

NEW WAR OF THE SPEED KINGS

POPULAR MECHANICS



MAGAZINE

WRITTEN SO YOU CAN UNDERSTAND IT

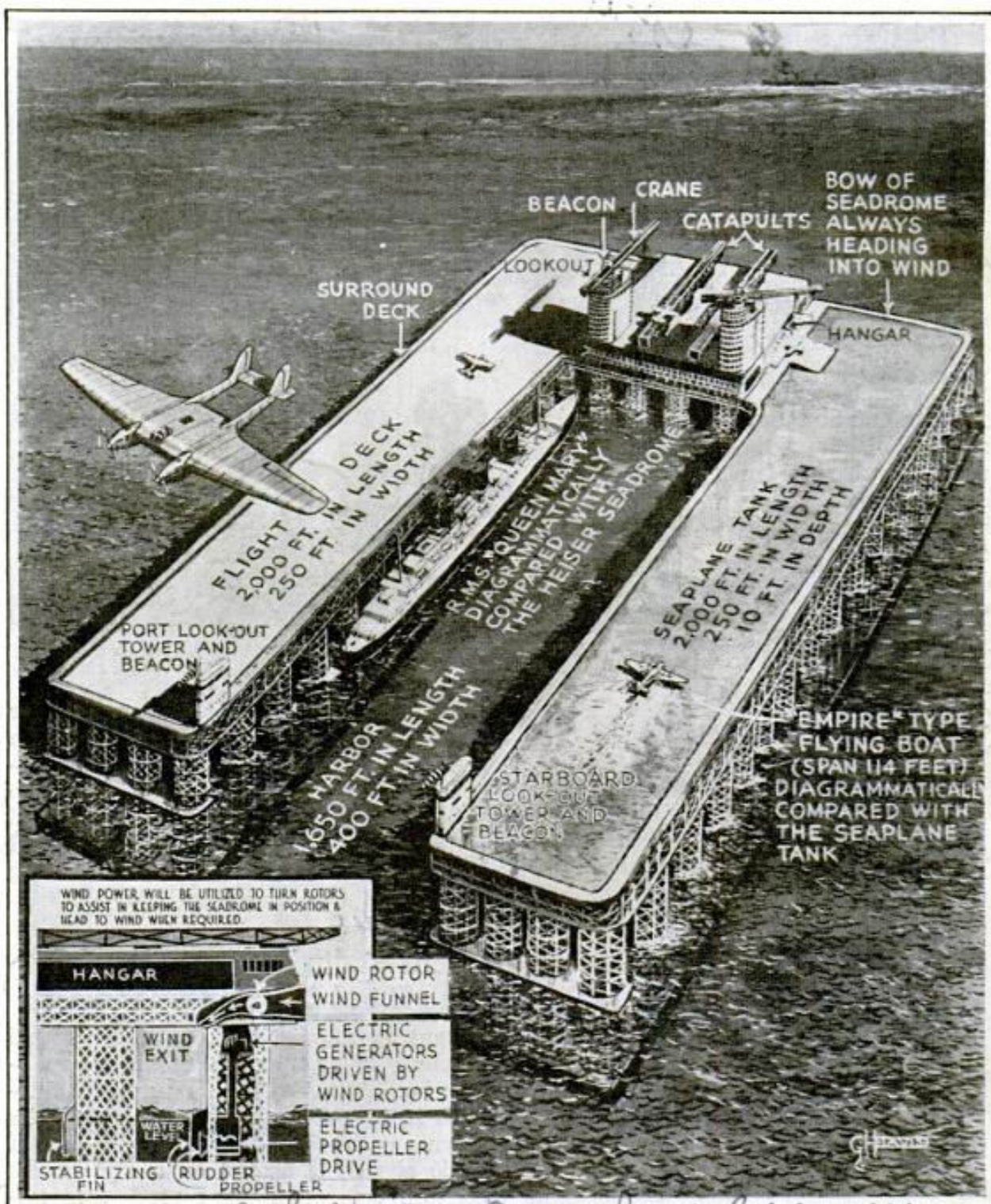
DESIGN TRADE MARK, GREAT BRITAIN, No. 40428

**JULY
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Is 263.

Floating Base Proposed for Ocean Air Liners



M.E. Heiser, Australian Engineer.

This is a drawing of the Heiser seadrome, proposed as a means of permitting land or sea planes to break their flights between Europe and the United States. The seadrome is U-shaped, with a 2,000-foot tank for flying boats and a 2,000-foot deck for land planes. Inside the "U" is a ship harbor, 1,650 feet long and 400 feet wide, large enough for liners of the "Queen Mary" type. The seadrome would not be anchored. It would be constructed of steel tubes built up on girder-work columns mounted on pontoons sunk 150 feet below the action of wave currents. Air currents agitate water to a depth of sixty feet, at which point pressure increases with depth until there is enough upward force to sustain the structure in position as the centrifugal force of the earth keeps the ocean in place. To help hold the seadrome into the wind, wind rotors would drive generators to supply power for twelve giant propellers. Two large rudders would be used for steering.

*506 - 47th Ave
San Francisco, Calif*

MAKE HOUSES FROM CARS OF BIG PARIS WHEEL



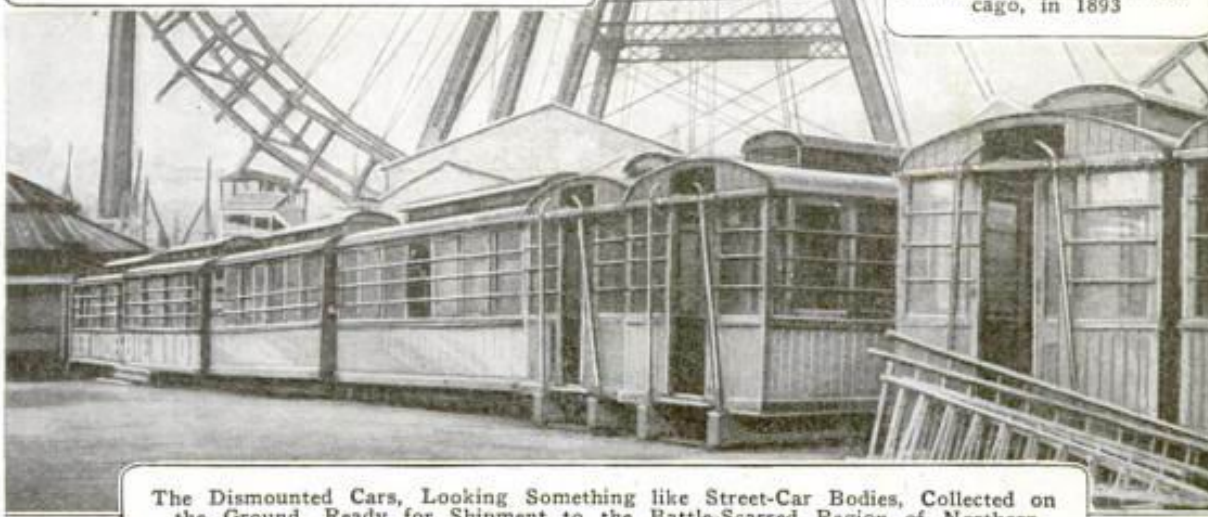
In the Big Wheel of Paris, Which has Stood for More than 20 Years as a Landmark of the Paris Exposition of 1900, Two New and Queer-Looking Spokes have Suddenly Appeared, Forming a Massive "V" in the Upper Half of the Giant Circle. They Are the Steel Scaffolds of Workmen Who are Now Engaged in Wrecking the Wheel



The Great Structure Is Still a Wheel, as Seen Here, but Its 40 Cars have been Removed, the Main Object of the Dismantling Work



The Wheel as It Appeared Just Before Demolition Began: It Was Practically a Copy of the Famous Ferris Wheel of the World's Columbian Exposition, in Chicago, in 1893



The Dismounted Cars, Looking Something like Street-Car Bodies, Collected on the Ground, Ready for Shipment to the Battle-Scarred Region of Northern France, Where They will be Made into Dwellings for the Homeless Inhabitants

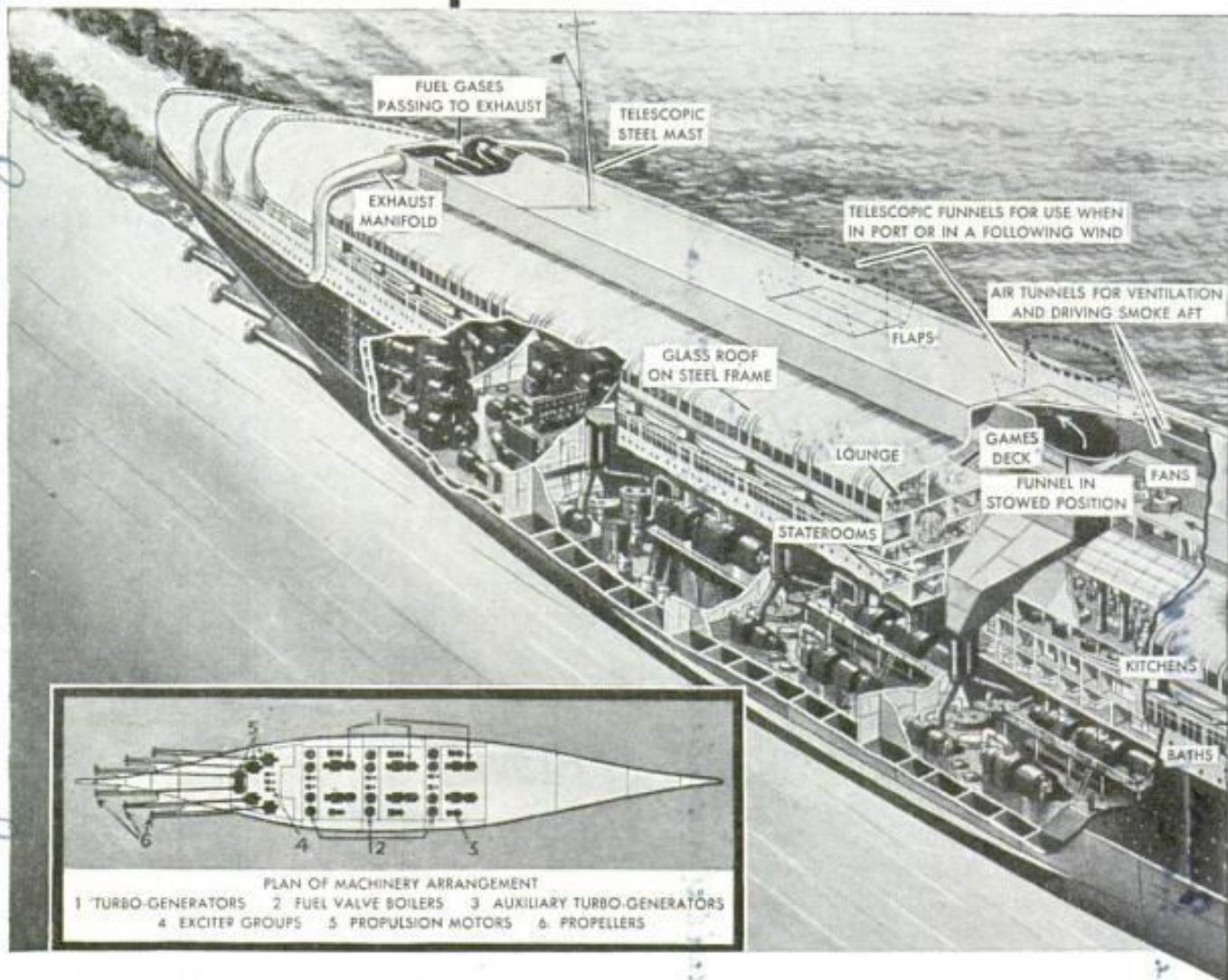


An Artist's Conception of a Future War Scene: Two Captive Helicopters, Restrained from Drifting by Their Anchor Ropes, are Watching the Outcome of an Engagement, and Fighting Off Enemy Air Craft with Their Machine Guns. A Third has Become Partially Disabled but Instead of Plunging to Annihilation It is Settling Earthward Gently, Sustained by Its Monster Parachute and One or Two of the Engines Which are Still Operating. Though It should Strike the Ground with Considerable Force, the Tightly Inflated Air Bags, at the Ends of the Frame Arms and in the Center, will Act as Buffers to Absorb the Shock and Prevent Serious Damage

Cmdr. Adham Pres. Ltd. (C. H. Parsons) Photo Sale
 manager / 93 Longacre London W.C.2, England

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THE LINER



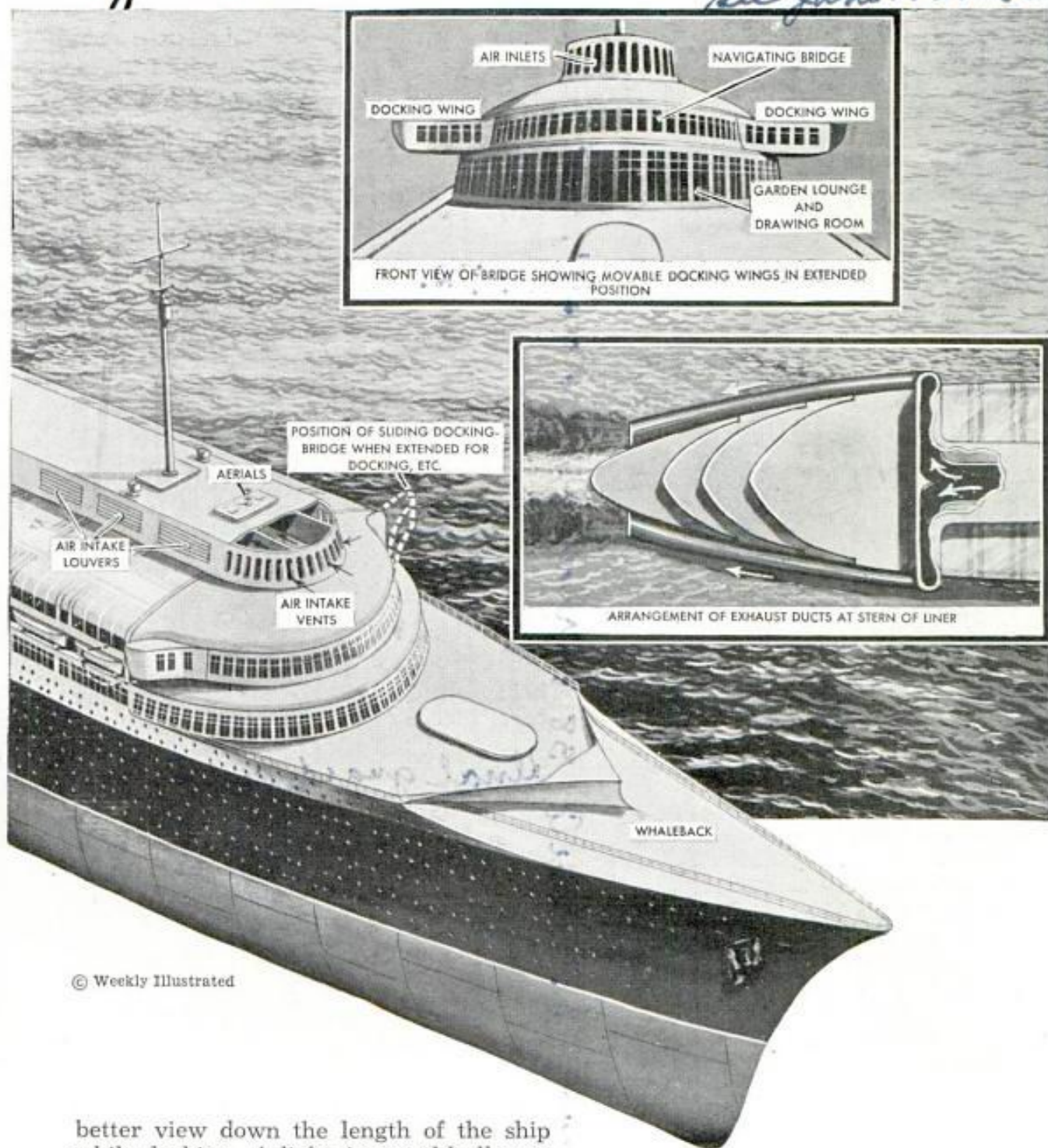
AERONAUTICAL designers already are putting on paper their plans for hundred-passenger air leviathans that will shorten the gap between Europe and America. Transatlantic air liners soon will be in real competition with ocean liners, and now marine engineers have begun to sketch plans for ships that can stay in competition with the fliers. One design proposes a six-screw vessel that could cross the Atlantic in three and one-half days, driven by six main propulsion motors of at least 66,000 horsepower each. Their current would be supplied by six turbo-generators with a capacity of 51,000 kilowatts each. Such a power plant, developing a total of around 400,000 horsepower—the “Queen Mary” rates about 200,000 horsepower—would consume 2,150 tons of fuel oil a day, requiring vast storage tanks and some method of ballasting to maintain

equilibrium as the oil is consumed. The engineers figure this huge streamline vessel could run five or six knots faster than any present ship, and more time could be made up by landing passengers at Montauk Bay and putting them on a fast “boat train” down Long Island to New York. This would save about ten hours, eliminating about 170 miles from the ship journey, besides the slow process of docking in New York harbor.

During a voyage, the fuel gases would be exhausted from vents at the stern. However, in harbor or in case of a strong following wind the gas would be diverted to two funnels, situated in the conventional place amidships but telescoping, when not in use, through flaps in the top deck. Another suggested innovation is a control bridge provided with movable wings which can be extended from either side for a

of the FUTURE

see June 1938. 887



© Weekly Illustrated

better view down the length of the ship while docking. A light, inverted hull over the main deck would provide a streamline superstructure. As much as possible, the designers propose to eliminate external gear; the lifeboats are under cover, and the steel masts telescope into the deck. The glass roof of the top deck is strong enough to resist the battering of Atlantic gales.

The superliner as planned by A. C. Hardy and Pierre de Malglaive would be

about 1,350 feet from bow to stern, compared with the 1,108-foot length of the "Queen Mary." Its cost has been estimated between forty and fifty million dollars—considerably under the figure to be spent on each of the superdreadnaughts projected for the U. S. navy. Construction would take three years or more, and provide work for thousands of men.

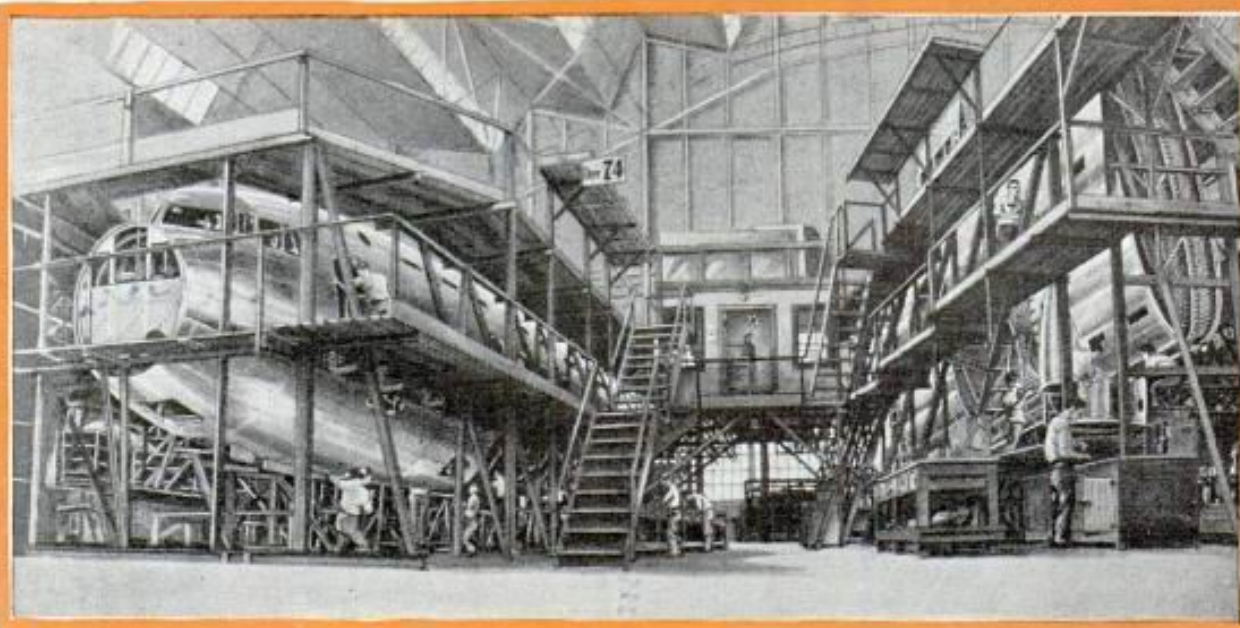
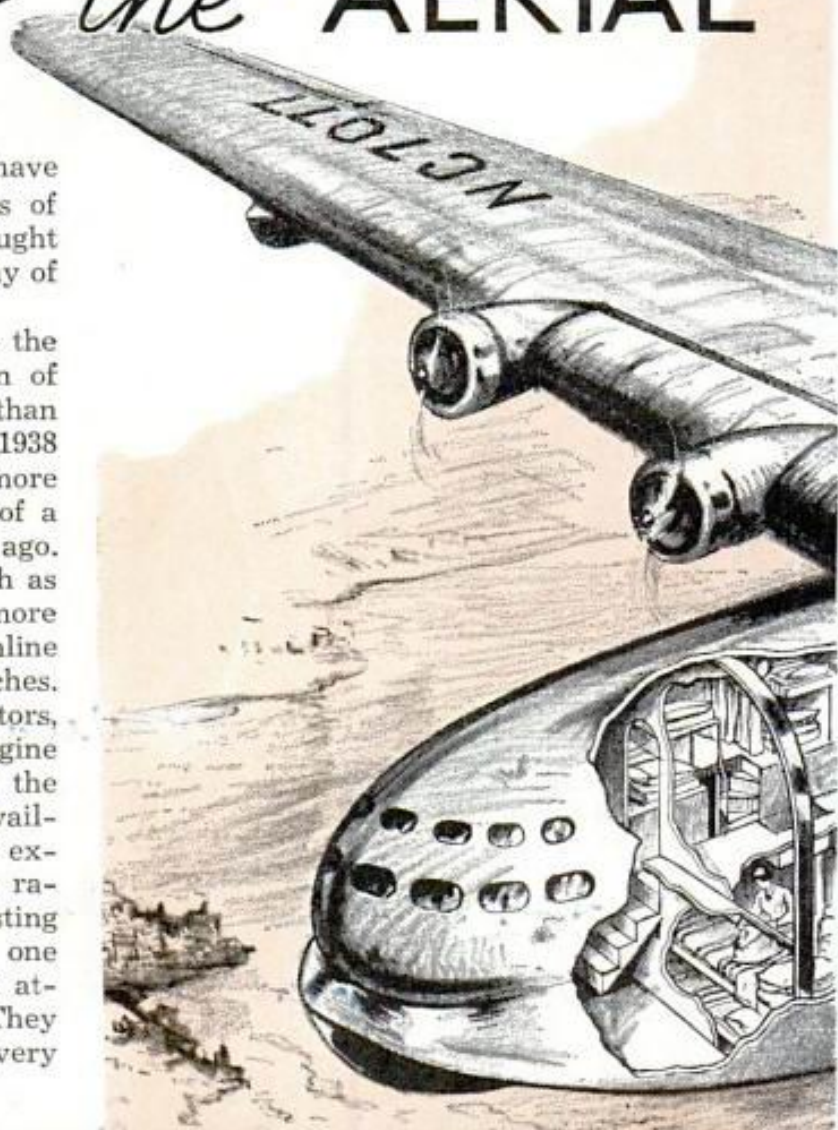
H 141 cmk. Thomas E. Stinson, Jr.
105 5,5 Holman Ave
Los Angeles Calif

AGE of the AERIAL

FOR years aviation engineers have been discussing giant airplanes of the future. This year they have caught up with their prophecies and the day of the aerial monsters is here.

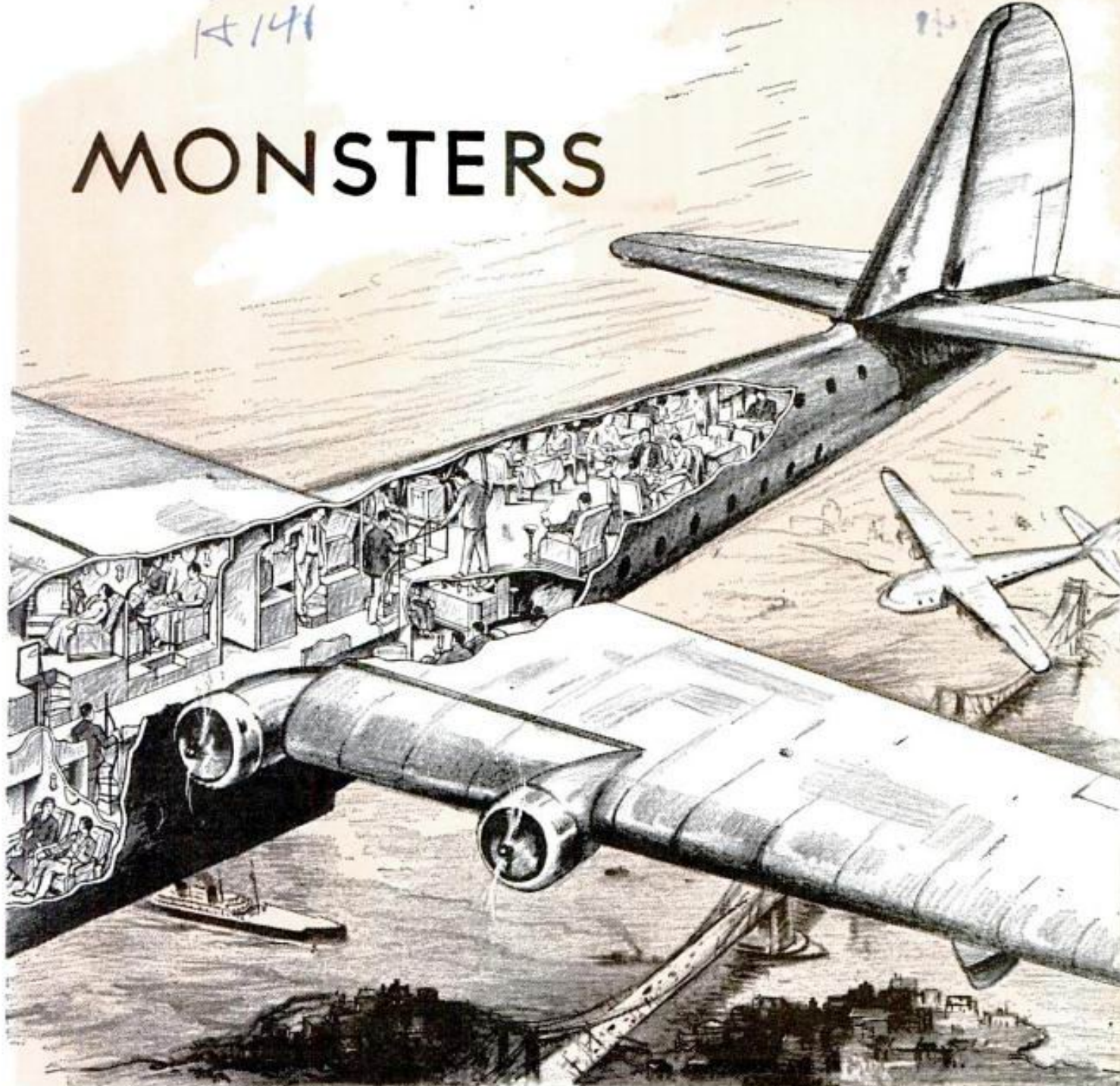
One thing that has helped make the dream come true is the perfection of aviation engines far more powerful than any of the past. One engine of a 1938 four-motored airplane develops more power than the total horsepower of a tri-motored transport of ten years ago. Four such engines provide as much as 6,000 horsepower for take-offs, more power than is required by a streamline engine to pull twelve railroad coaches.

These tremendous air-cooled motors, the latest developments of the engine manufacturing companies, are on the "military secret" list and are not available to everyone, nor may they be exported abroad. They are twin-row radials of improved design, consisting essentially of two radial engines, one placed right behind the other, and attached to a common crankshaft. They develop one horsepower for every pound and a quarter of weight.



Bottom, view of workmen busy on giant fuselage and wings of Douglas transport, DC-4. The scaffolding forms a sort of dry dock in which the plane was assembled like a ship

MONSTERS



Drawing of interior of Consolidated's version of transoceanic air liner. Note the double-deck arrangement and luxurious accommodations, very similar to those of ocean liners

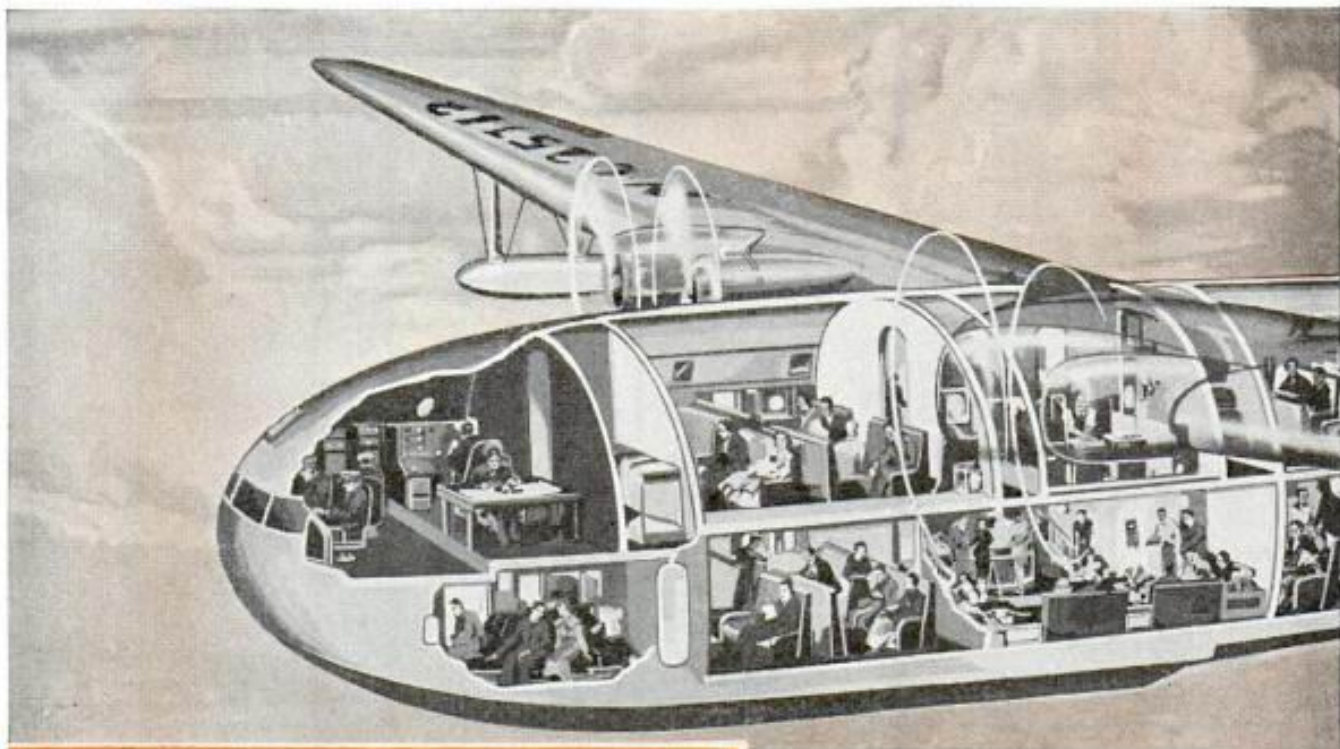
The new airplanes made possible by these engines actually dwarf the present giants of the airways. The new DC-4, to be launched soon by the Douglas Airplane company, was assembled like a ship, in a sort of dry dock.

The DC-4 has nearly three times the gross weight of the big Douglas transports now in service. The four-motored plane has a wing spread of 139 feet. Its fuselage is ninety-seven feet long and it stands twenty-four feet high. It will carry forty-two passengers and a crew of five, as well as three and a half tons of mail and express. The plane will have a top speed of around 237 miles per hour at 8,000 feet, a

cruising radius of 2,200 miles, and a service ceiling of around 23,000 feet. The plane weighs 65,000 pounds fully loaded and will be able to cross the continent with only one stop. Research, engineering, and construction costs on this first giant amount to one and a half million dollars. The plane was built at the joint order of the five leading domestic air lines. The idea of this united action is to develop a standard type of super-transport.

Instead of settling down on a tail wheel in landing, the DC-4 will land level with the ground with its tail remaining in the air. The plane uses a retractable tricycle type of landing gear that employs a nose

*A. M. Kochlen
Public Relations Sec.*



Top, nose of Martin's concept of transatlantic air liner. Bottom, mock-up of DC-4 passenger compartment

wheel instead of a tail wheel. The two huge main landing wheels are twenty-six feet apart.

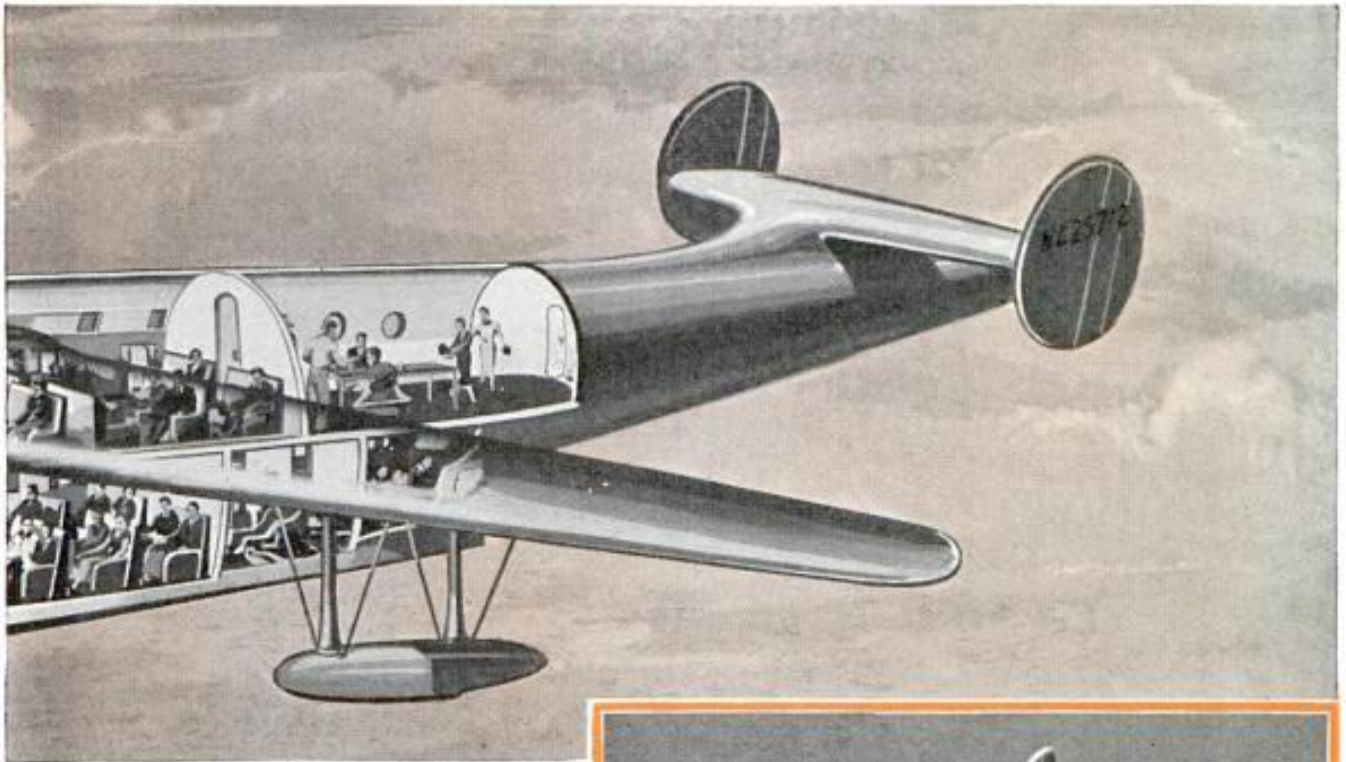
Instead of a conventional tail the plane has triple vertical tail surfaces. The new arrangement allows better control with half the power plants not operating. The horizontal airfoil surface of the tail group is about the size of the wing of a small bomber. Control surfaces are so large that manual control by the pilot is augmented by hydraulic booster pumps. Some of the control cables are nearly one-half inch in diameter. For the first time in a large airplane, flat flush-type rivets are used in fastening the outer metal skin, materially reducing resistance.

To make sure their calculations provide

the needed safety factors Douglas engineers performed more than 300 major physical tests and approximately 1,000 minor tests before construction really started. Hundreds of thousands of dollars were spent on building up vital parts of the plane and then testing them to destruction. The special anti-frost laminated glass for the cockpit windows was subjected to temperatures of forty degrees below zero to make certain that it remain transparent under extreme conditions.

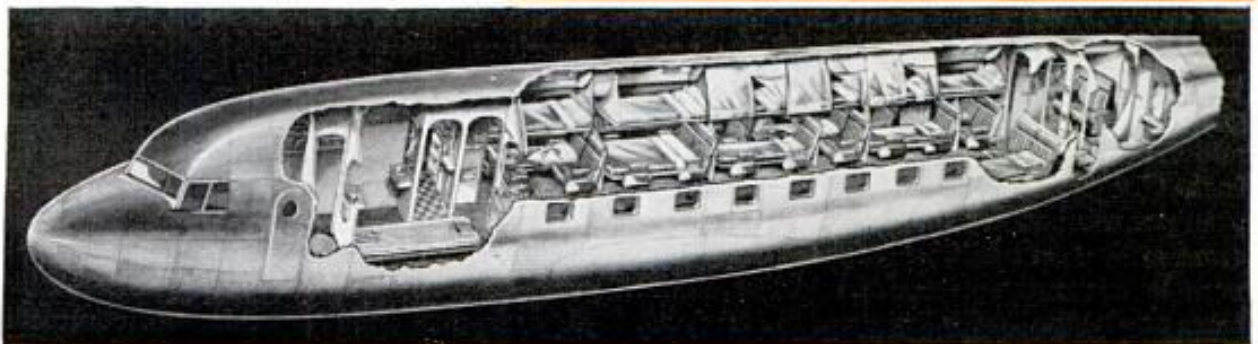
Approximately 20,000 pieces of metal, fittings, and sheets, exclusive of rivets, were used to build the plane and inspectors stationed in the dry dock approved every part before it could be added to the structure.

The lighting and other secondary power requirements are so heavy that auxiliary engines instead of batteries are used for the circuits. These air-cooled auxiliary engines drive alternators furnishing enough 800-cycle 110-volt current to light a huge office building. They also operate vacuum pumps for instrument-operating vacuum, provide pressure for the de-icers, run a hydraulic pump for the autopilot, and furnish pressure for the main hydraulic system that operates the air flaps, landing gear, and the minor hydraulic units. The



exhaust systems of these engines pass into the exhaust pipes of the propelling engines, being located so as to pass through steam boilers for cabin heating, making heat for the boilers available even when the plane is standing on the ground with the main propelling engines not operating.

Inside the huge cabin various arrangements of comfortable lounge chairs, reclining chairs, or sleeping berths are to be installed according to the desires of the different air lines. The different plans all include dressing rooms and a large galley under the care of a steward and stewardess. There are thirty-two windows in the



Top, interior of Martin plane shows passengers at play. Center, model of the DC-4. Bottom, interior arrangement of DC-4, showing deep, comfortable berths for traveling at night

F1289 Cont. James Mc Incey
9 & 45 th St., Kansas City, Mo

The FLYING WING



Building the first all-metal transport designed by the author. This is the Lockheed Electra, famed for its speed. Here we see workmen busy on wing and nose

By Hall L. Hibbard

Chief Engineer, Lockheed Aircraft Corporation

TOMORROW'S airplane—a giant flying wing without fuselage or cabin, carrying payloads of 150 passengers and tons of baggage.

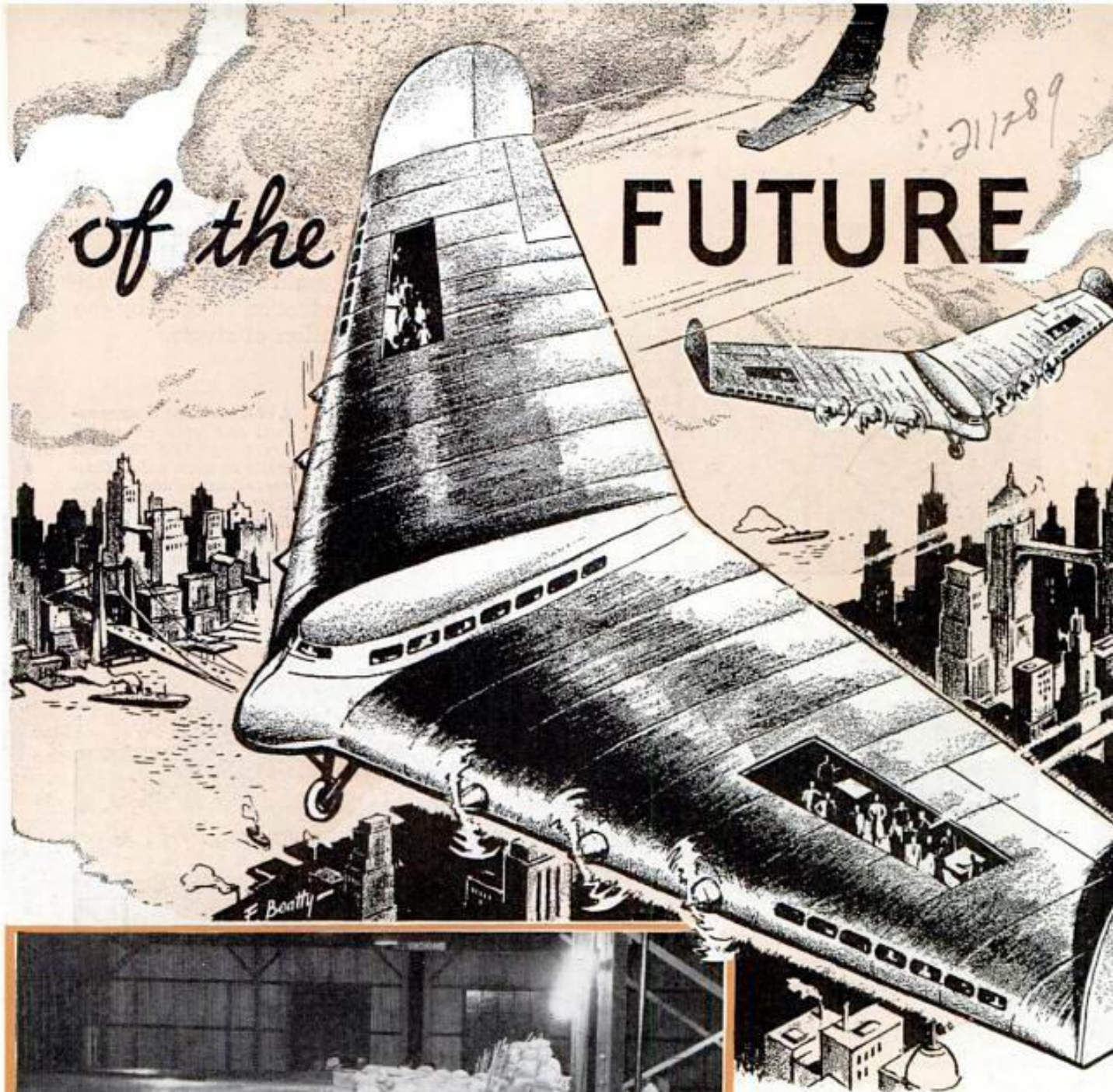
Judging from present developments and trends in aircraft design, it is our belief that such is a rough sketch of the commercial transport that will be flying the sky trails within a decade or so. Of stainless-steel construction, it will be almost twice the size of any plane now under construction with a gross weight of 150,000 pounds and having a tip-to-tip wing spread of 300 feet. For power, it will use six 2,500-horsepower motors, so arranged that the mechanics may work on them during flight.

Travelers will ride inside the giant wing, which will be equipped with individual

staterooms, recreational facilities and a promenade deck. Curved windows will be placed in the leading edge of the wing, in the ceiling and parts of the floor. To complete the picture, the tricycle landing gear will be used to land the big transports.

The speed with which these flying wings will travel is difficult to predict. Because we have learned that size has little bearing on speed, 500 miles an hour is not improbable, if certain problems regarding altitude flying can be answered satisfactorily. Speed costs money. The faster a plane travels the more fuel used and the greater the depreciation on equipment, all of which means higher operating costs.

The prediction of such radical changes will not meet with the favor of those who



Top, drawing of the "flying wing" envisioned by the author. Left, static load test of a new Lockheed. Plane is inverted and sandbags weighing far in excess of any weight the plane will carry are placed on the wings

flying wing is not beyond the range of future possibility, we need only to compare one of the earlier planes with a modern transport.

feel the ultimate in aeronautical development has been reached. But aircraft designers are not hidebound by precedent or production methods. They have a way of looking beyond the artificial limitations of their tools and in so doing make possible the "impossible." For evidence that the

In efforts to improve aircraft, engineers and technicians have sought to eliminate useless, dragging elements. Struts, braces, and guy wires have disappeared. On the big ships, the next important step is removal of the fuselage. And with it will go the tail, lateral and vertical control being attained through

U. S. DRIVERS AGAINST THE WORLD

POPULAR MECHANICS

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THE MAKING OF A RACE DRIVER

POPULAR MECHANICS

MAGAZINE

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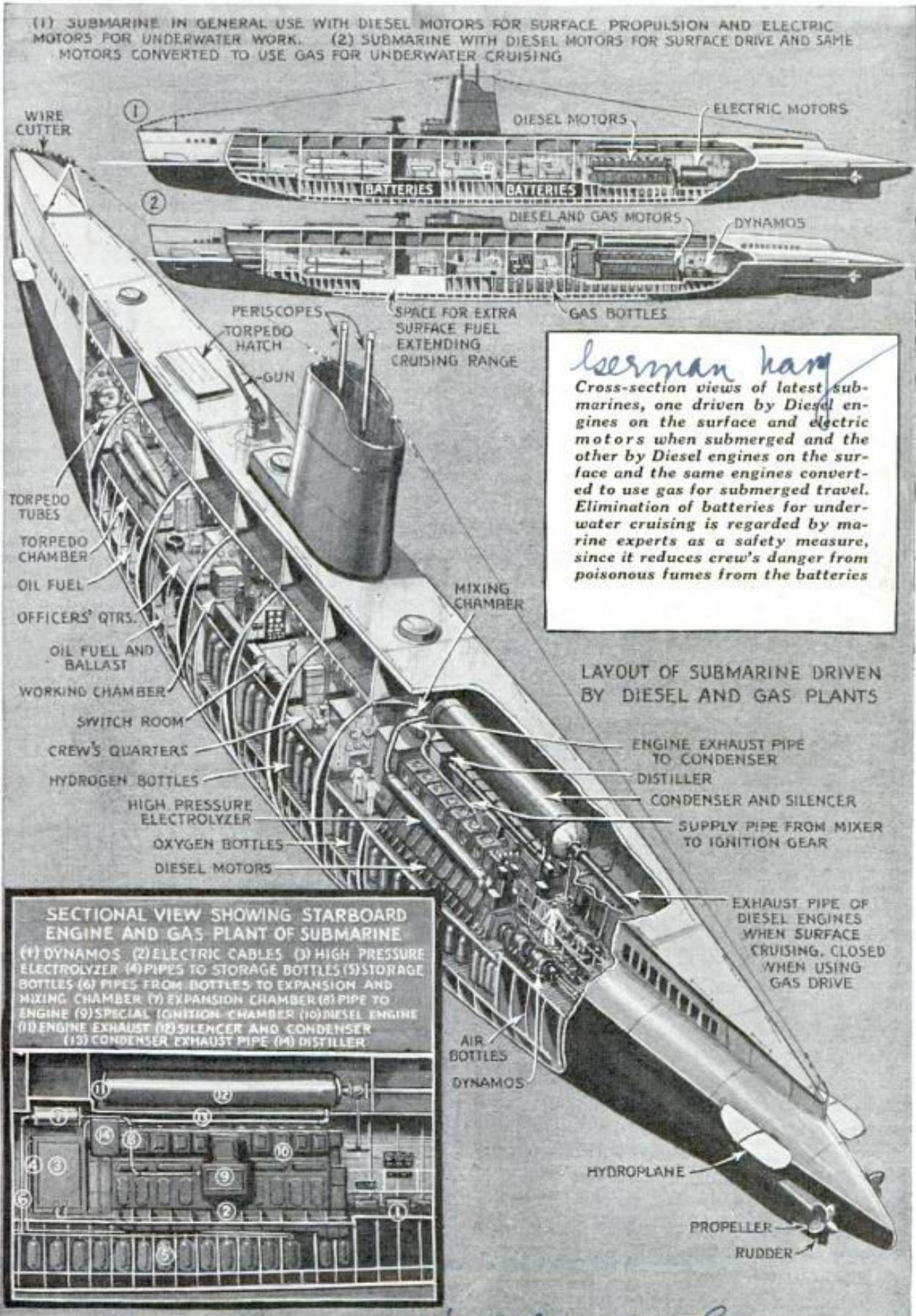
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Gas-Driven Submarine Safer under Water



Capt. George H. Davis, Esq.
Linnets, 1 Hillside Road, Ewell,
Surrey, England

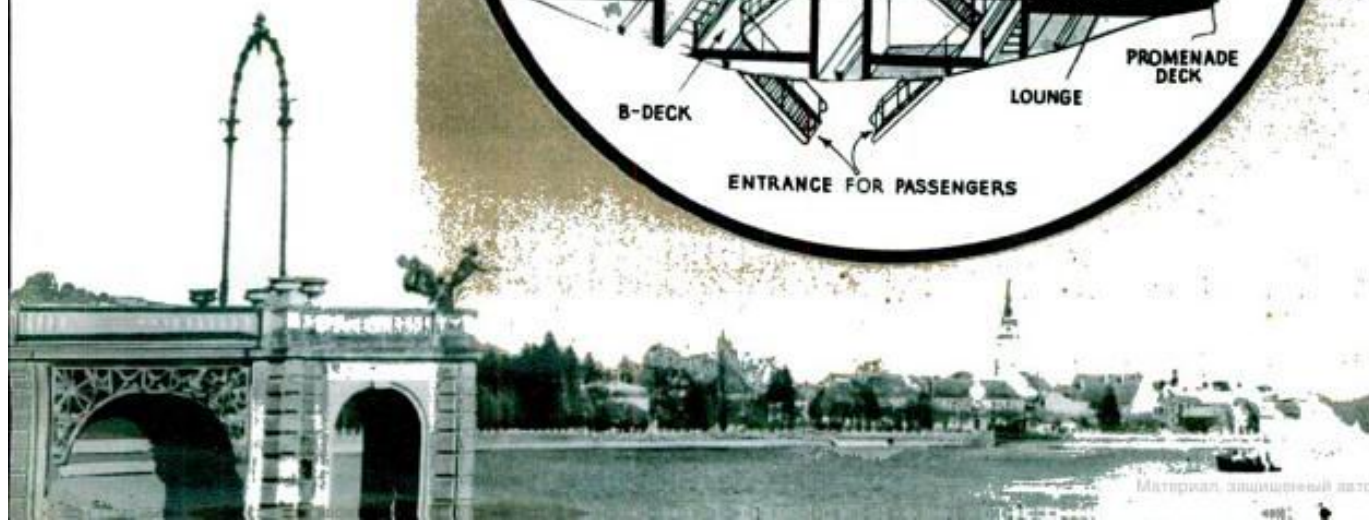
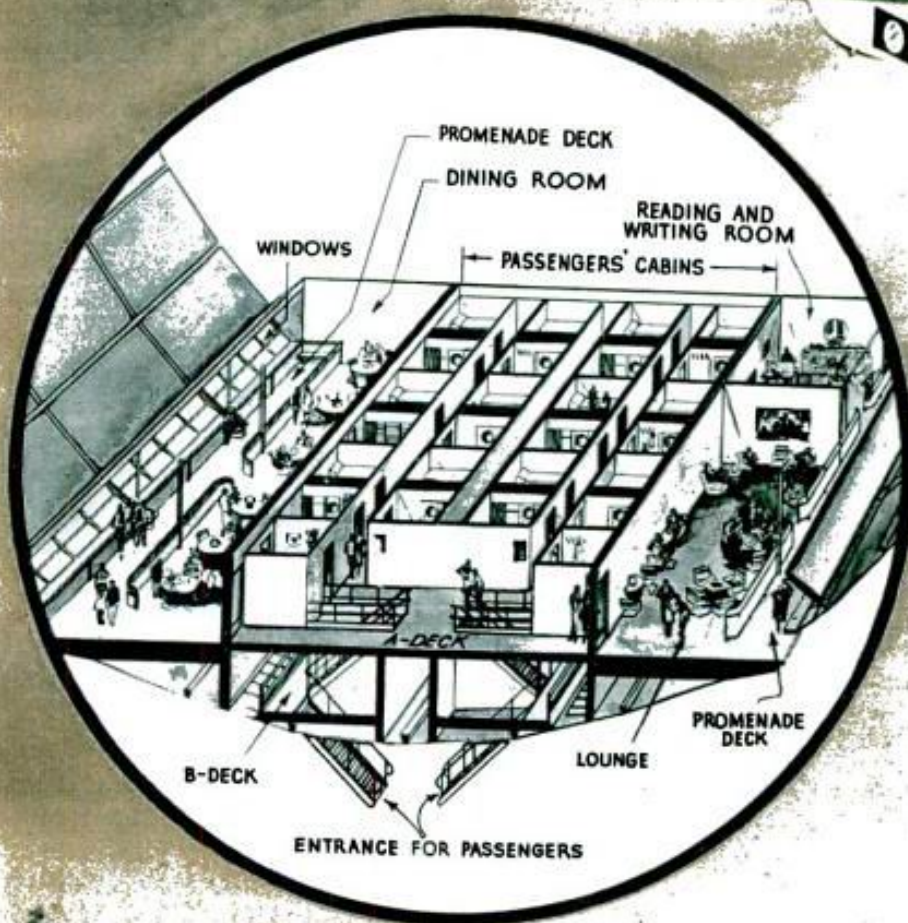
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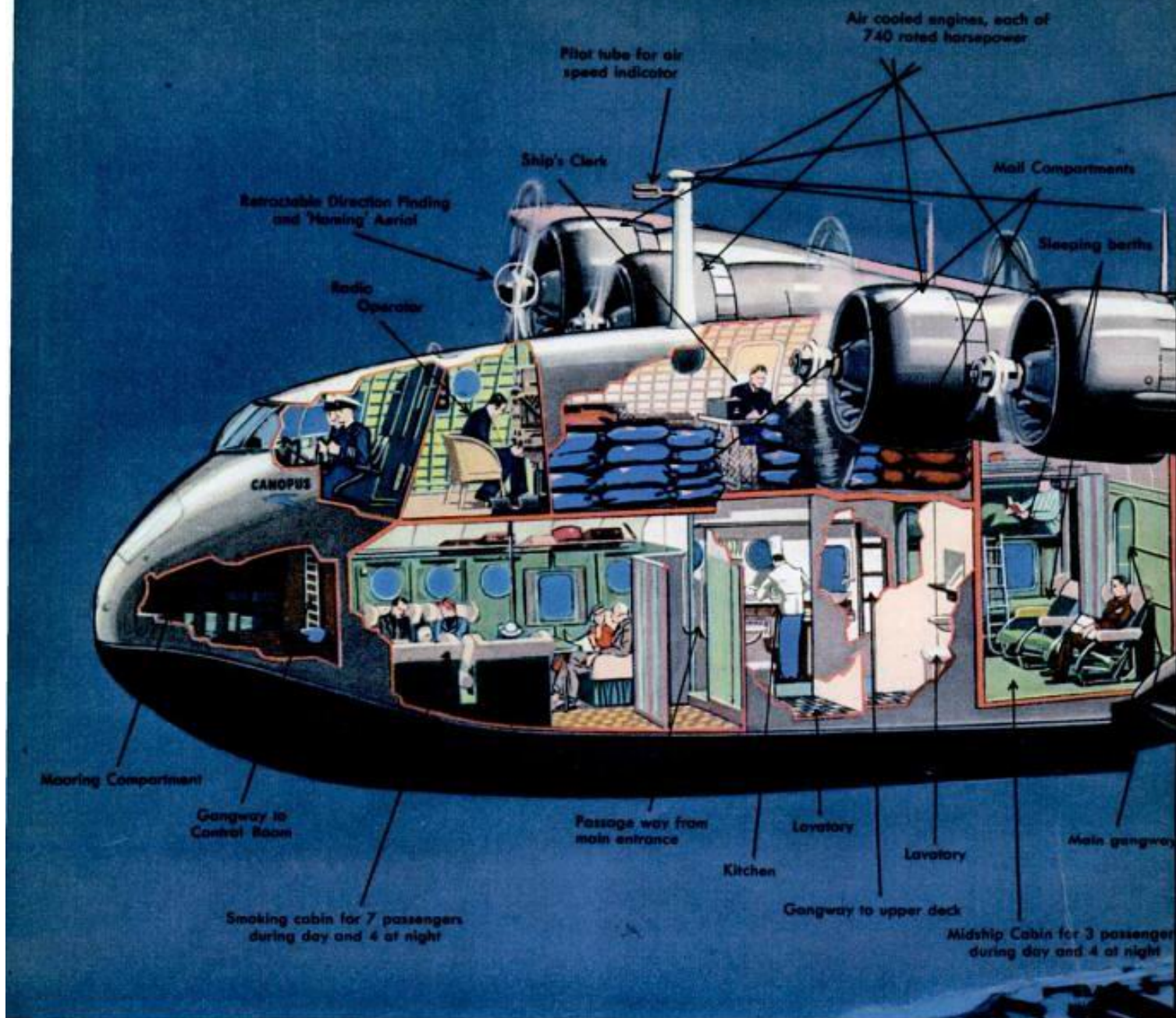
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Photos courtesy Deutsche Zeppelin Reederei

ACROSS the Atlantic, you travel on the "Hindenburg," the world's largest Zeppelin. Above is the radio room of this giant dirigible and at the right, above, is the writing room. The diagram below shows the layout of the passenger quarters and the public rooms on the "Hindenburg."





FLYING boat of Imperial Airways, above, with accommodations for twenty-four passengers by day and sixteen at night. It weighs eighteen tons. On opposite page is a smaller type of Imperial Airways plane.

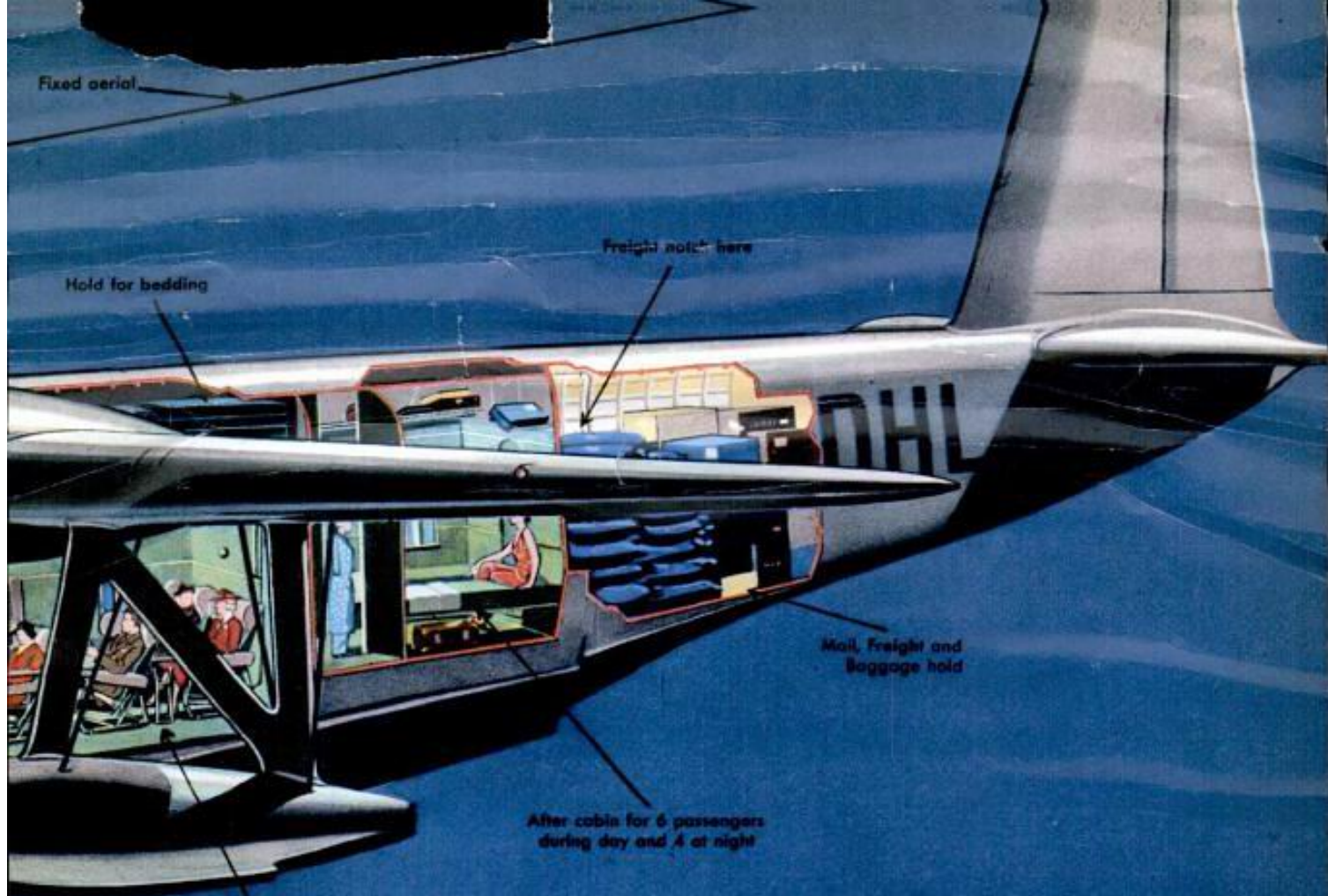
has been a challenge and a goal for adventurous man. Magellan's little flagship, "Trinidad," accomplished it first in 1522. It took 1,083 days—three years. In 1580 Sir Francis Drake started the business of breaking records. He cut a month from the "Trinidad's" time.

Since then, with a steadily increasing tempo through the centuries, globe-girdlers have been chopping years, months and finally, weeks, days and hours from the time. In 1874 Jules Verne wrote "Around the World in Eighty Days." People laughed and called it a fantastic dream. Fifteen years later Nellie Bly electrified the world by actually beating

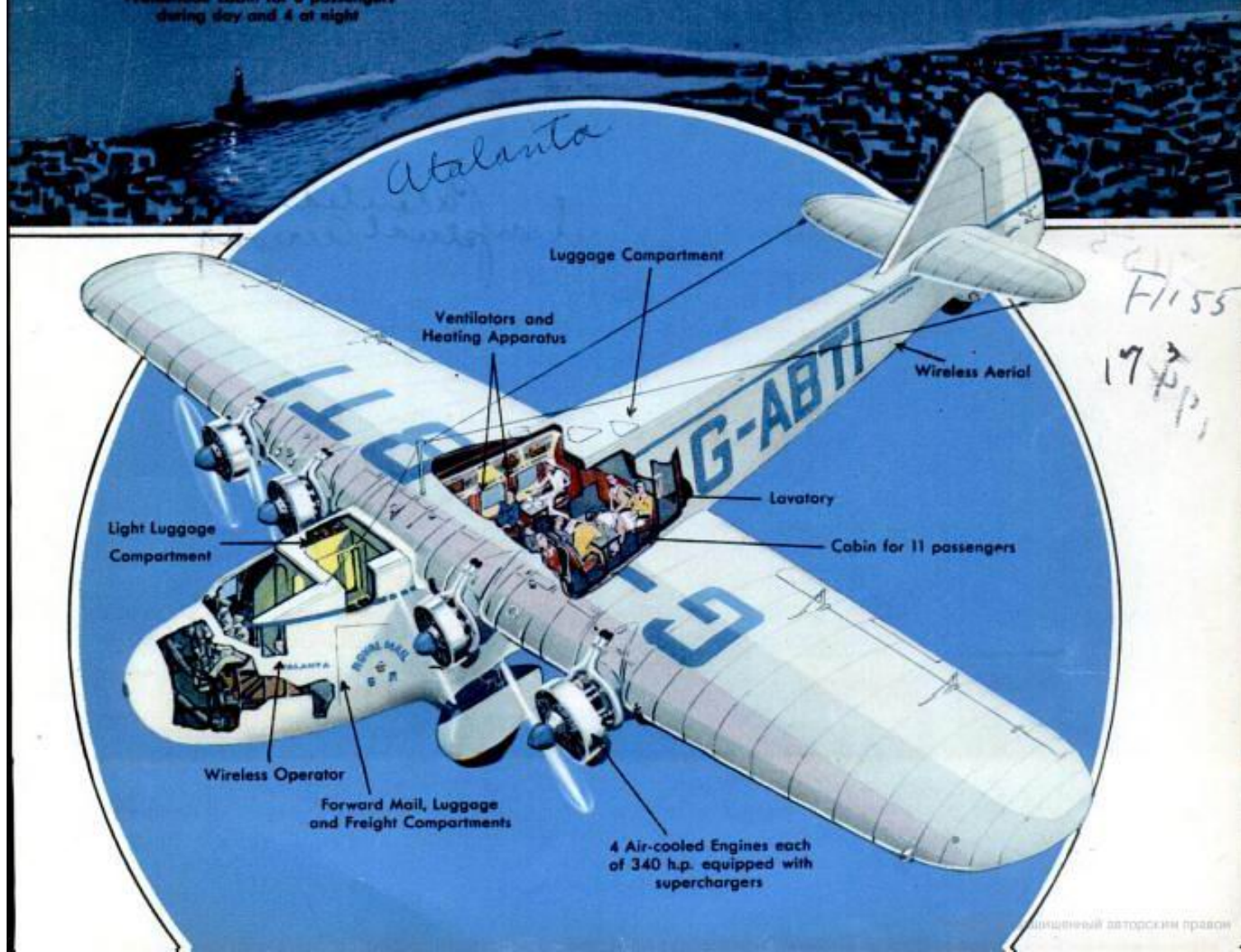
Verne's "dream time" with her seventy-two-day journey by rail and boat. Fourteen years after that, John Mears made it in thirty-five days.

Then came the airplane to speed travel in a new element and the globe-girdlers really started to get dizzy. In 1926 Edward S. Evans and Linton Wells, using airplanes, boats, trains and automobiles, got around and home again in twenty-eight days. A couple of years later Mears and C. B. D. Collyer cut the time to less than twenty-four days.

And then, in 1931, Wiley Post and Harold Gatty climaxed all these feats with their brilliant flight around the



Promenade cabin for 8 passengers during day and 4 at night





SLEEPER plane of American Airlines with upper and lower berths arranged like those of a Pullman coach.

AROUND
the WORLD
by AIR

F1155

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B-2 Stealth bomber—flanked by B-1, lower left, and B-52, top right—takes to the air over Edwards Air Force Base on its first flight.

IRRESISTIBLE FORCE

The \$530 million B-2 Stealth bomber joins the B-52 and the B-1 in forming a Strategic Air Command capable of defeating diverse threats. But the American public must decide if the price is just too high.

BY TIM COLE, Science/Technology/Aerospace Editor

BRIEFERS AT Strategic Air Command headquarters in Omaha, Nebraska, are starting to call it an "integrated force package." But the marriage of flight-weary B-52s, as yet unfinished B-1Bs and politically explosive B-2s looks more and more like "something old, something new."

Nonetheless, as controversy and debate swirl and eddy around the air-

breathing leg of America's nuclear deterrent, Air Force leaders continue the task of modernizing SAC's bomber platforms—crucial, they say, to the process of waging peace. Who's to argue? Like it or not, the strength of America's bomber force has helped prevent global conflict for more than four decades—in a game of brutal logic that only makes nuclear war all the more unimaginable.

The current doctrine? Aging but still viable B-52s, capable but cantankerous B-1Bs and revolutionary but hugely expensive B-2s will work in concert to knock out key targets in the event of a nuclear strike—and to assume a conventional role in times of low-intensity conflict. Each brings unique attributes to SAC's power mix, forming a new weapons suite that, with hope and skill, can stand up to an evolving Soviet threat for another 40 years and beyond. Vast expense and technological uncertainty casts a pretty tall shadow on this otherwise optimistic outlook.

To understand the changes taking place in America's Strategic Air Command, *POPULAR MECHANICS* interviewed senior military leaders like SAC Commander-in-Chief General John T. Chain, and attended the B-2 rollout, meeting with engineers and officers of Northrop Corp. We also flew in the B-1B, making PM one of

IRRESISTIBLE FORCE

the few publications to place a representative aboard America's low-level penetrator (see "Fail Safe '88," page 54, Jan. '88). And on our recent ride on a low-level B-52 mission through America's heartland we observed the simulated release of air-launched cruise missiles, a new role for the mighty Stratofortress. Our interviews, technical briefings and flight time have given us a comprehensive understanding of where SAC is headed. B-52s and B-1Bs already stand alert. But significant hurdles must be overcome before the B-52, B-1B and B-2 can coalesce into an interdependent force of devastating destructive potential—a potential that, ironically, may be the key to a lasting peace.

A look back

While the Northrop B-2 Stealth bomber was capturing headlines, keeping the B-52 flying and fighting despite its increasingly geriatric airframe was the preoccupation of flight crews at scattered SAC bases.

Improved East Bloc surface-to-air missiles and the B-52's immense radar cross section have turned America's oldest bomber (it was first manufac-

tured by Boeing in 1952) into a superb delivery vehicle for air-launched cruise missiles. These weapons upgrades in the face of a significantly greater threat have transformed the B-52 into a logical platform for eliminating certain targets—particularly early-warning sensing devices—at standoff ranges.

But the Strategic Air Command is also formulating plans to turn part of the B-52 fleet into a low-level attack bomber in a conventional scenario. SAC planners foresee the need for deep interdiction of enemy troops and supplies in time of theater conflict. Upgrades in night-vision and terrain-avoidance gear will allow conventionally armed B-52s to fly to long-range targets in any weather. Just a handful of bases around the world—from Diego Garcia in the Indian Ocean to Keflavik in Iceland—gives the B-52 virtually global coverage.

The B-52's offensive avionics have been upgraded, and the ALQ-172 electronic countermeasures system has proven successful. Other conventional warfighting equipment include the GPS global positioning system for precision navigation (soon to become

fully operational), an infrared night vision system and head-up display (a highly unusual technology transfer from the fighter community) and an offensive avionics system (OAS). Similar to ground-attack systems found in F-16s and F/A-18s, the B-52's OAS senses altitude, barometric pressure, inertial navigation plot and other factors, evaluates target data, and adjusts the plane's inbound course and weapons release.

Equipped with Harpoon antiship missiles and mines, the B-52 can easily convert to sea patrol plane, adhering to a concept SAC planners call MASS, or Maritime Air Sea Surveillance. MASS calls for protection of shipping lanes in the event of an East Bloc attack on Western Europe.

Fast forward

While the future of the B-52—assisted by avionics upgrades and careful airframe monitoring for signs of stress—has never appeared brighter, it's been anything but smooth sailing for the Rockwell B-1B. Failure of the Eaton Corp. ALQ-161 electronic countermeasures system to perform according to manufacturer's claims



TOMORROW'S SAC BOMBER MISSION

In a greatly condensed artist's view of the future strategic battle space, B-52s lead a strike using air-launched cruise missiles to knock out enemy sensing platforms and airfields. B-1Bs firing short-range attack missiles and dropping gravity bombs strike fixed missile silos and SAM sites. The B-2 penetrates heavier defenses to eliminate hardened or mobile missile sites.

has been a lightning rod for criticism of the \$275 million swing-wing bomber. Crashes due to bird strikes and pilot error haven't helped the B-1B's reputation, nor have pesky but persistent anomalies like fuel leaks.

But the world's first low-level strategic penetrator has earned high praise from air crews, who fly the B-1B through the world's roughest terrain. "Fighting" the B-1B is tough physical and mental work, as I discovered on that training flight out of Dyess Air Force Base in Abilene, Texas. It takes some pretty aggressive flying to execute terrain-masking tactics through densely wooded mountain passes. The low-level rationale becomes immediately clear when you're clearing ridge lines by 100 ft. at 550 knots. While chaff, flares, radar location and warning systems and terrain-following radar give the B-1B some potent (though still not perfect) capabilities, its real strength is this ability to fly low at high subsonic speeds, often within the crags and chasms of the topography, to foil enemy detection methods. Indeed, the smaller, faster, more agile B-1B carries greater payload than the B-52

and drops it with greater accuracy.

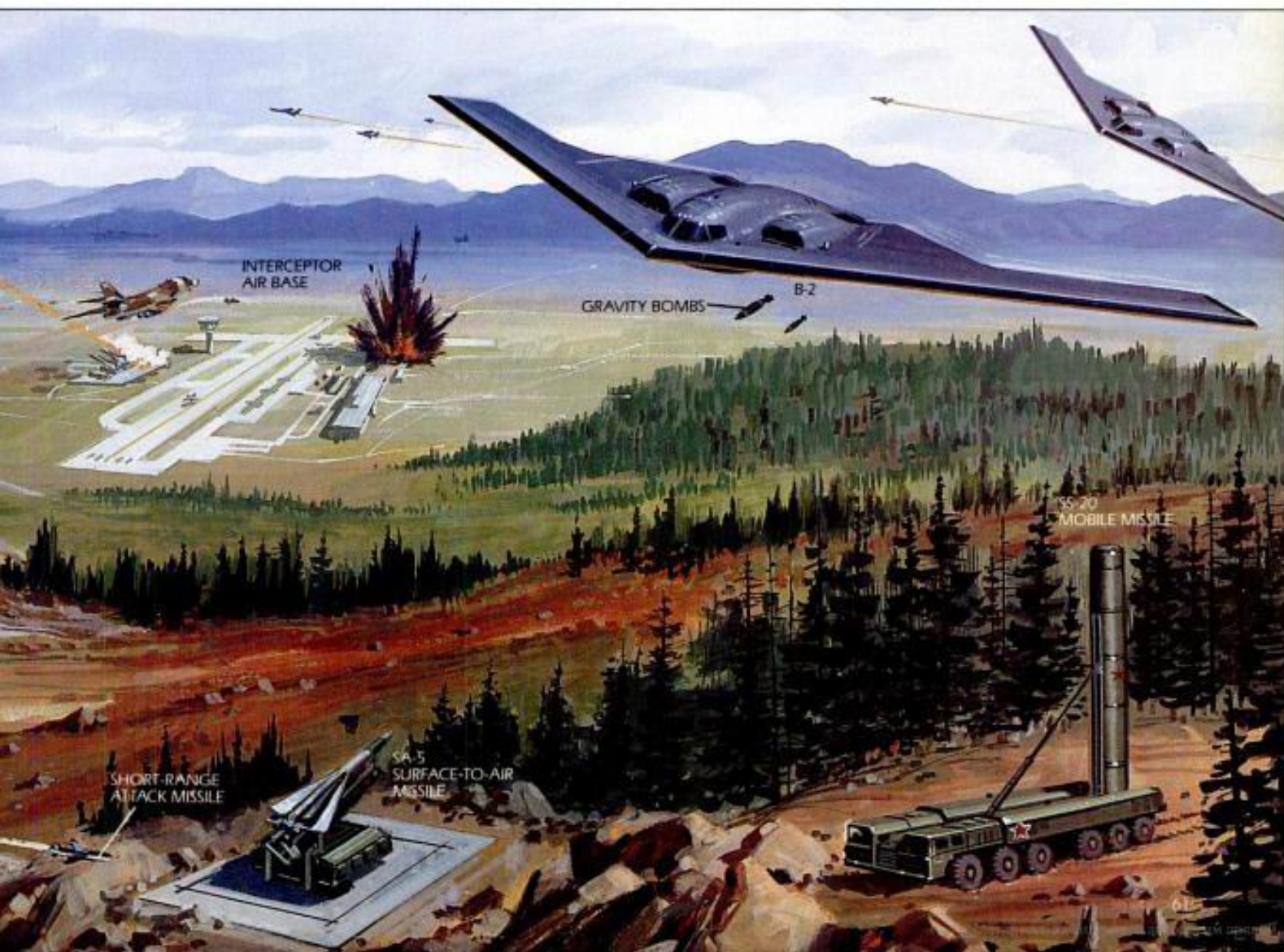
Despite its shortcomings, SAC must depend on the B-1B more and more as time passes, not only as a means of penetrating Soviet air space with gravity bombs, but as a standoff platform for advanced cruise missiles as the Soviet threat evolves. The B-1B also has on its side one very sobering and incontrovertible fact. The B-2 is several years from full production, if it ever passes Congressional budget scrutiny, making the decision to buy the B-1B all the more astute.

The new technology

As with any expensive, complex weapons system, the B-2 is hardly without criticism. Detractors charge that the latest generation of ground, spaced-based and bistatic radars, not to mention advanced optical and infrared sensors, will detect the B-2 as it penetrates Soviet air space to strike hardened or mobile targets. They say that billions in stealth technology can not protect B-2 from easy interception once detected, and that standoff cruise missiles will perform the mission more accurately at less risk. They also point out that the B-2 mis-

sion of finding and eliminating relocatable ICBM launchers depends too heavily on satellite reconnaissance, which will be eliminated in the first phase of a general nuclear exchange. General Bernard P. Randolph, commander of Air Force Systems Command which is developing the B-2, forcefully disagrees, ticking off B-2's advantages. A 6000-mile unrefueled range and an effective 50,000 pound internal weapons load of short-range attack missiles, nuclear gravity bombs or conventional ordnance give B-2 a formidable punch in a variety of mission scenarios. B-2s flying from just four bases—two in the states and two overseas—could cover most of the world's hot-spots with just one refueling.

The B-2's flying-wing platform, first proposed by Jack Northrop for the YB-49 back in the late 40s, is thought by the Air Force to embody the proper combination of load carrying, flight efficiency and low observability. If a B-1B has a radar cross-section $\frac{1}{100}$ th that of a B-52, the radar cross-section of a B-2 is said to be $\frac{1}{10}$ th that of a B-1B—giving the B-2 the appearance of a bird on an enemy



IF YOU THINK THE ARMY'S M1 LOOKS MEAN ON THE OUTSIDE, YOU OUGHT TO SEE WHAT IT LOOKS LIKE ON THE INSIDE.

This 60-ton monster is made up of more than 35,000 highly specialized parts—from its giant 1500 horsepower engine to laser circuits no bigger than an eyelash.

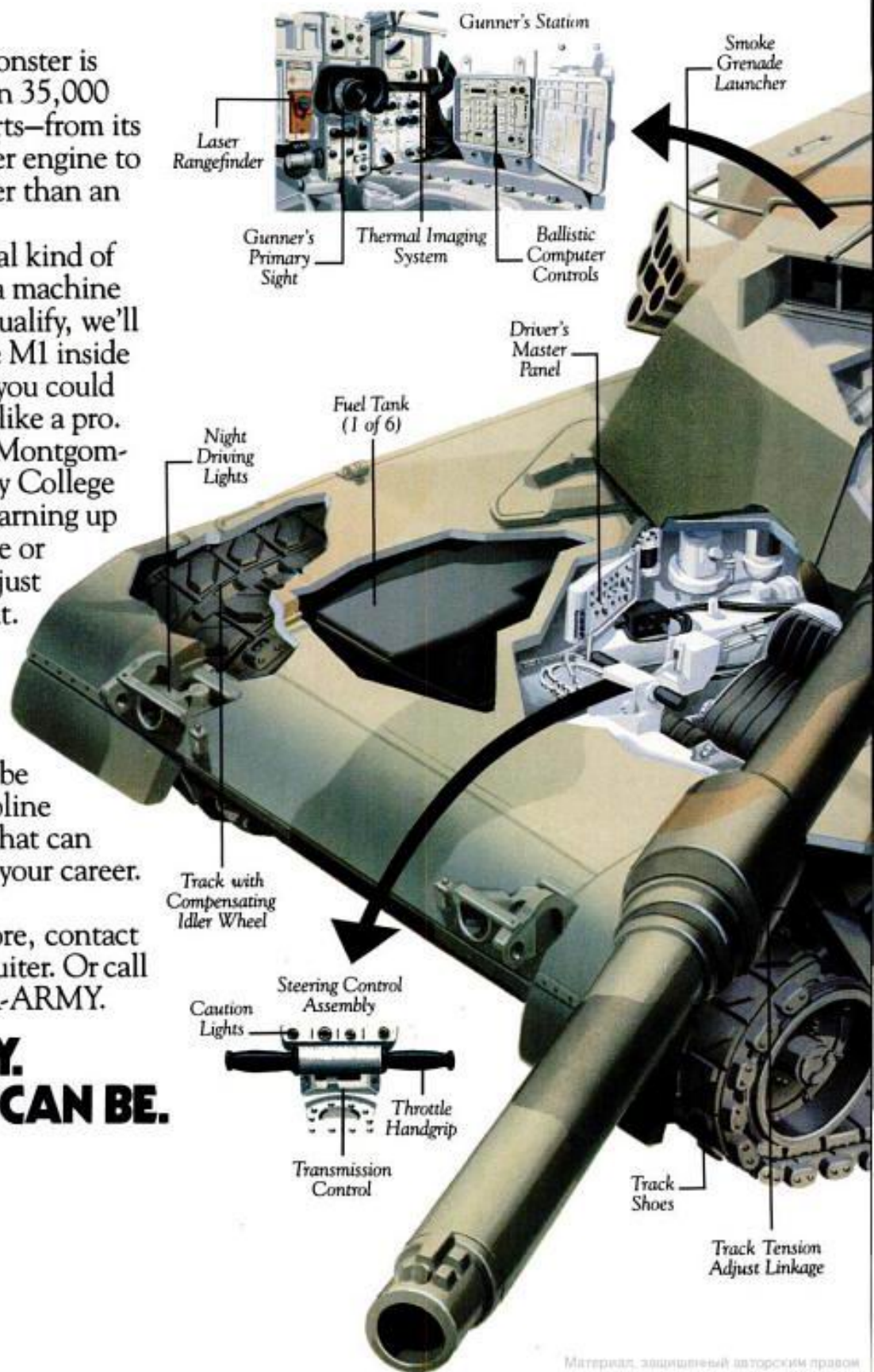
It takes a special kind of mechanic to master a machine like this. But if you qualify, we'll train you to learn the M1 inside out. So before long, you could be working on tanks like a pro.

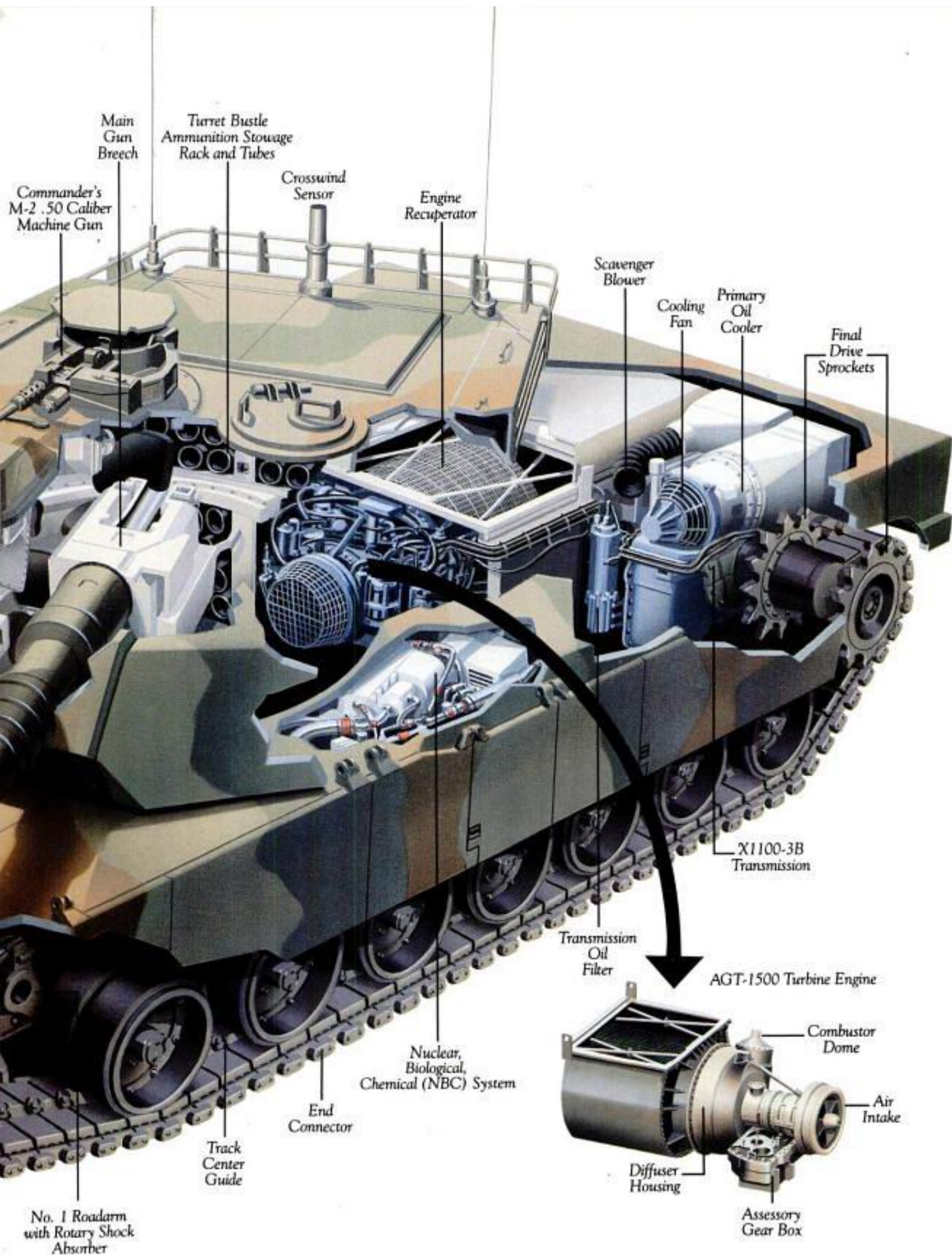
And with the Montgomery GI Bill Plus Army College Fund, you could be earning up to \$25,200 for college or vo-tech school with just a four-year enlistment.

Most important, while you're developing your technical skills in the Army, you'll also be developing the discipline and self-confidence that can give you an edge. In your career. And in life.

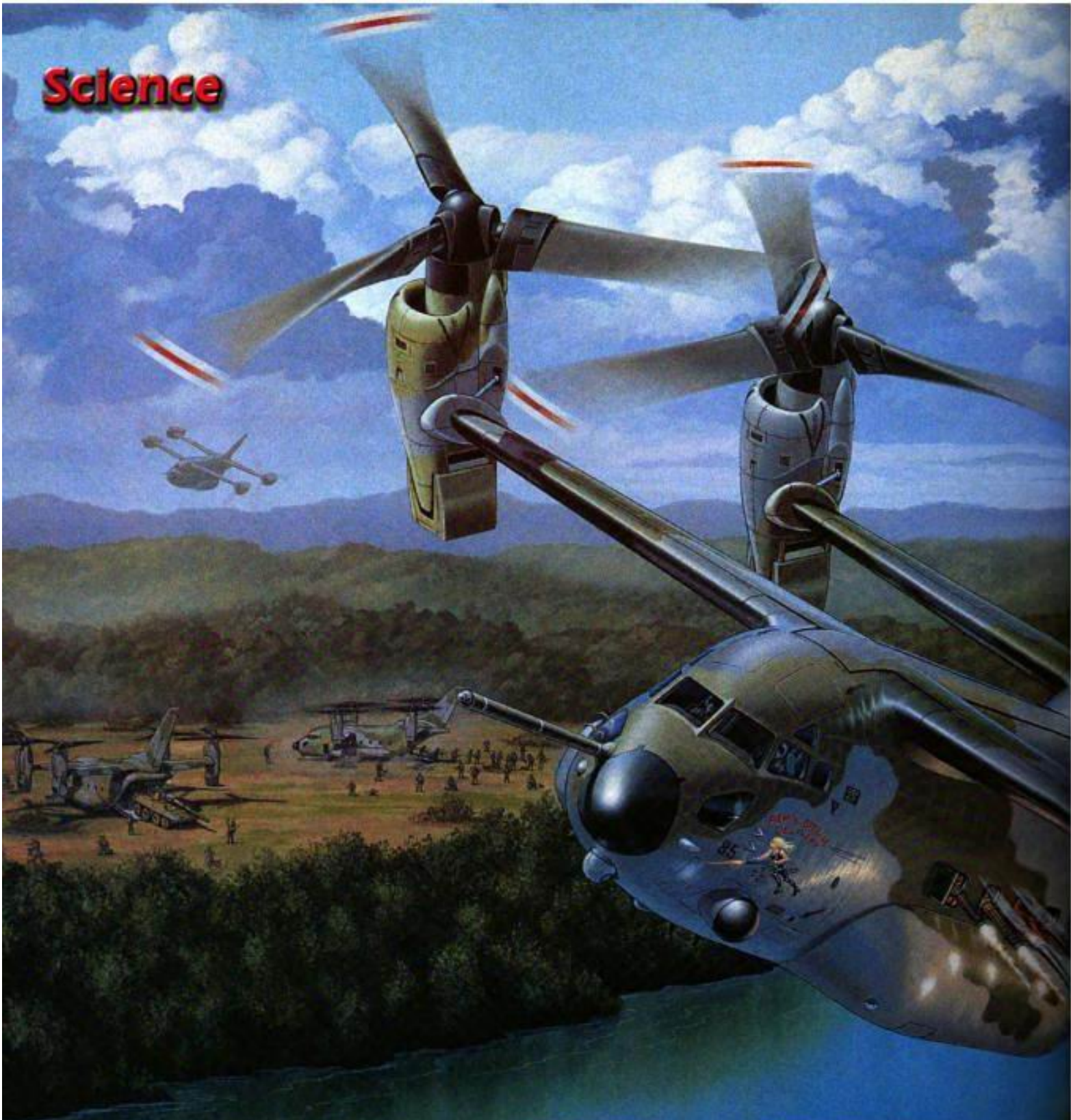
To find out more, contact your local Army recruiter. Or call toll-free: 1-800-USA-ARMY.

**ARMY.
BE ALL YOU CAN BE.**





Science



V-44

The Pentagon's next transport flies like a plane, lands like a helicopter and unloads enough firepower to start—or stop—a war.

BY SCOTT R. GOURLEY, Illustration by Mark McCandlish

► Some planes are so

beautiful they could hang in art museums even if they couldn't fly. Others—the Wart Hog tank-killer comes to mind—are as homely as their names. And then

COVER STORY

there is the Pentagon's next wonder-plane, the V-44. It's ugly, coyote ugly, with wings. Four wings to be exact. Each is tipped with a tilting nacelle that converts the V-44 from a helicopter that can land or take off wherever a truck can make a U-turn to a 300-mph fixed-wing transport, troop carrier or gunship. Still on the drawing board, the

plane we've informally designated the V-44 derives from the V-22 Osprey, a two-wing tiltrotor that is now undergoing final evaluations by the Marine Corps. The need for a quad-rotor version stems from what defense analysts predict will be fundamental changes in the nature of war in the 21st century. Desert Storm was your father's war. Tomorrow, low-intensity conflicts will be the rule as the anointed battle the infidels, plant police take on drug barons, and taxmen shoot it out with money launderers.

Uncle Sam has decided to step into the fray as the policeman of this new world disorder. His billy club will be a new military deployment strategy that puts ready-



"The FTR concept can be traced back to the 1960s when the Curtiss-Wright Corp. built the X-19."



to-fight brigades on the ground in 96 hours. American armed forces will get into the action on a new type of plane, the V-44 Future Transport Rotorcraft (FTR).

Twice A V-22

The FTR will provide a capability that does not exist anywhere in the world today—and perhaps will replace the helicopter for military operations. The concept for the aerial assault platform comes from Bell Helicopter Textron. Having teamed with Boeing on the twin-engine V-22 Osprey tiltrotor program, Bell has developed the concept for a larger fuselage. Envisioned to be about the size of a stretched C-130 Hercules, the FTR would feature two V-22-type wings, each having an engine and a combination rotor-propeller mounted at the outboard tips. The exact configuration has yet to be determined. Some versions show a tailless aircraft, others have an airframe more along the lines of a C-130.

There is no disagreement about the interior. The V-44 is designed to be a heavy hauler. "Imagine this aircraft with a cabin large enough to internally carry an 8 x 8 x 40-ft. container, several helicopters, all types of high mobility multipurpose wheeled vehicles, light armored vehicles, eight standard loading pallets, or 70 [medivac] litters," reads an industry analysis describing the concept. "Imagine an aircraft that could transport 80 to 100 troops or 10 to 20 tons of equipment and supplies at speeds greater than 300 mph over distances from 1000 to 2000 miles and

A quad tiltrotor could be put into production as early as 2010.



then safely land vertically, without the need for runways or airports."

The FTR concept can be traced back as far as the early 1960s when the Curtiss-Wright Corp. built the X-19, a small quad-rotor testbed. After 50 successful test flights, it was destroyed in an accident. A second X-19 was scrapped. Enthusiasm for the FTR, however, is based on the technical success of the V-22 Osprey. These aircraft can be configured to carry 24 combat troops or up to 20,000 pounds of internal or external cargo at twice the speed

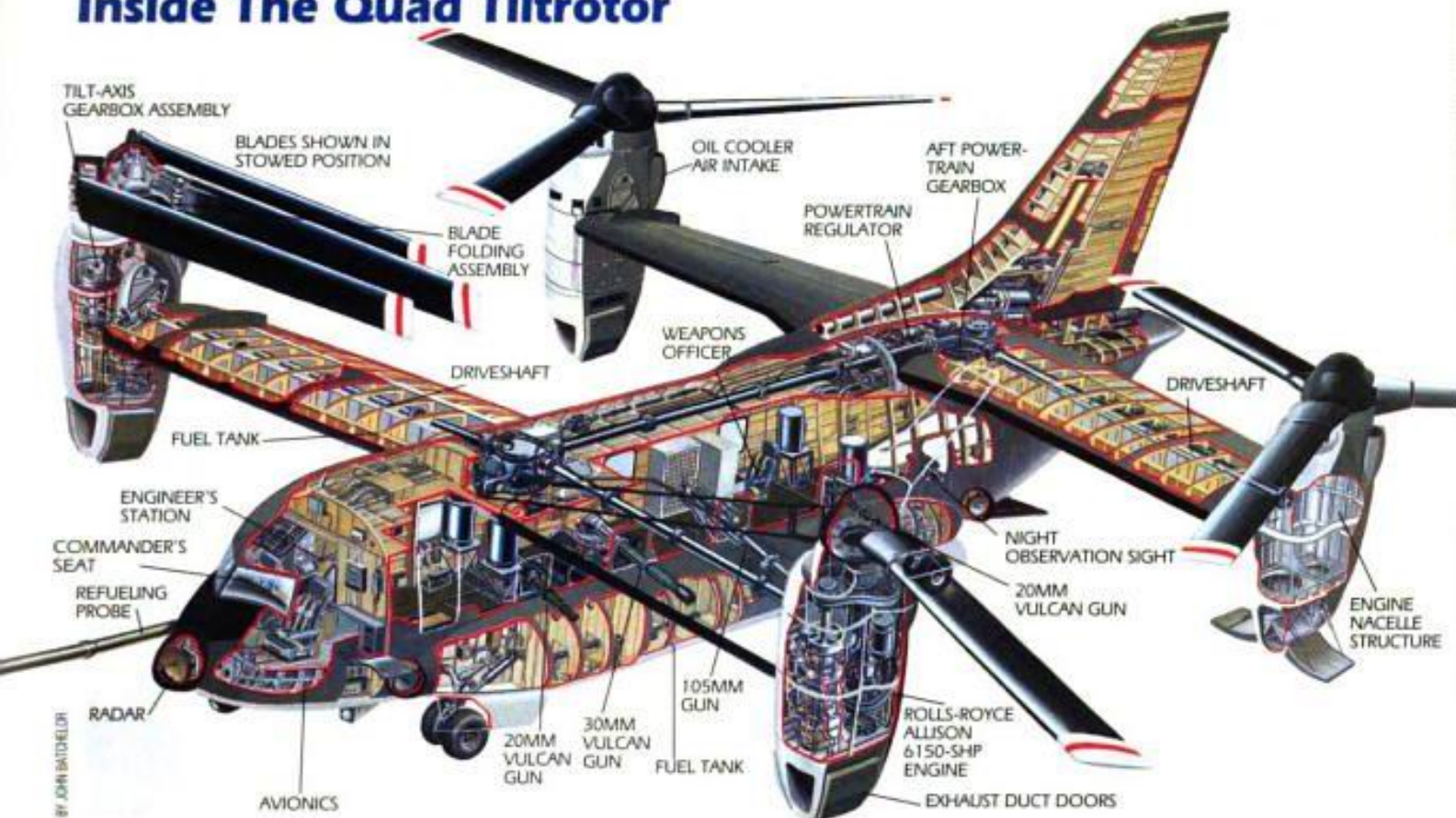
of a helicopter. U.S. procurement plans call for 360 Marine Corps MV-22 aircraft and 50 U.S. Air Force CV-22 aircraft. Using parts common with the Marine MV-22, the Air Force CV-22 modification includes the addition of internal-wing fuel tanks and terrain-avoidance and terrain-following radars. It also has been given an enhanced electronic warfare suite, additional cockpit seating for a flight engineer, an aerial refueling probe and an internally mounted rescue hoist.

The FTR will use a pair of V-22 propulsion systems. Each is based on two Rolls-Royce Allison AE 1107C 6150-shp engines and a

computer-controlled rotor coordination system that permits a safe landing if one engine loses power.

An obvious question is whether the four rotors could operate in such close proximity without creating turbulence that would shake apart the aircraft or make it impossible to control. To answer this question, Bell draws on data reaching back to its X-22 ducted propeller quad tiltrotor, which flew 500 flights between 1966 and 1988. The results encouraged Bell to test a pair of V-22s at a distance approximating

Inside The Quad Tiltrotor



the spacing between the fore and aft wings of a V-44. According to Dick Spivey, Bell's director of ad-

operations, support Air Force Aerospace Expeditionary Force units and meet many Army require-

ability to transport 8 to 12 tons of cargo over 600 miles with return at cruise speeds of 300 knots. Bell Helicopter engineers believe that their FTR concept would come very close to meeting these criteria.

A Formidable Gunship

In addition to the FTR's cargo-hauling abilities, the possibility of putting tiltrotor technology into combat can be seen in another industry analysis. With advanced laser weapons and precision fire control, the craft could provide protection for overtaking a captured or damaged airport or sea-port, making such sites accessible to allied forces.

Gunship applications are just one of several ideas being explored. A joint panel is looking at all of the rotorcraft possibilities. "They're looking at joint common lift replacement aircraft, to include a medium assault, a utility and an attack and anti-armor aircraft," explains Marine Corps Capt. Aisha Bakkar-Poe. "The Marine Corps' view is that tiltrotor is the way of the future because it has such a longer range and goes so much faster that it almost makes a helicopter obsolete."

PM



Troop buildups would no longer require runways.

vanced concepts, the test was a success. Water tunnel tests showed that the rotor wakes from the front engines flowed down and inboard—below and inboard of the rear rotors. Technically, there is no reason this bird shouldn't fly.

Thus configured, it could carry twice the payload and eight times the internal volume of cargo transported by the V-22. A true multiservice aircraft, it would reportedly meet the expanded needs of the Marine Corps' Ship-To-Objective Maneuver

ments for a future Joint Transport Rotorcraft (JTR). In the Army's case, officials envision a JTR that will replace some of the aging CH-47 Chinook helicopters. The Navy has its eye on the quad tiltrotor to make deliveries to its ocean-going fleet, much as the C-2A Greyhound now services carriers.

Early requirements issued by the Defense Department call for the

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HOW TO BLOW UP A BUILDING

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SEPTEMBER 2000

Popular Mechanics

**BEST
CORDLESS
SAWS**

FLYING FREIGHT TRAIN

DO NOT REMOVE FROM
CURRENT PERIODICALS ROOM

**Radical Quad-Engine
Tiltrotor V-44 Lifts 20 Tons
And Needs No Runway**

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CARS AT
THE MAX**
Our Test Sifts
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The Brute

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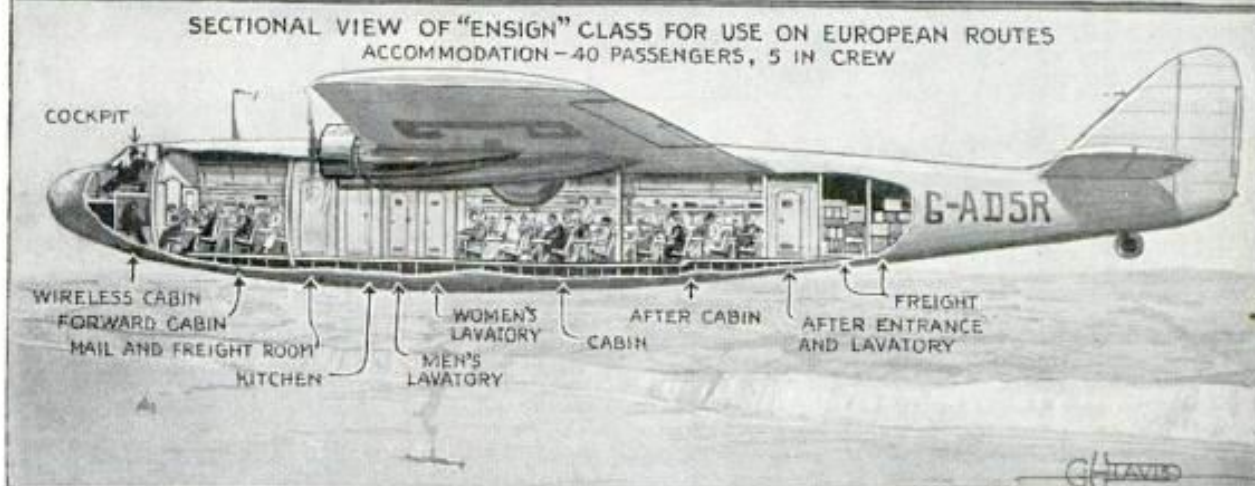
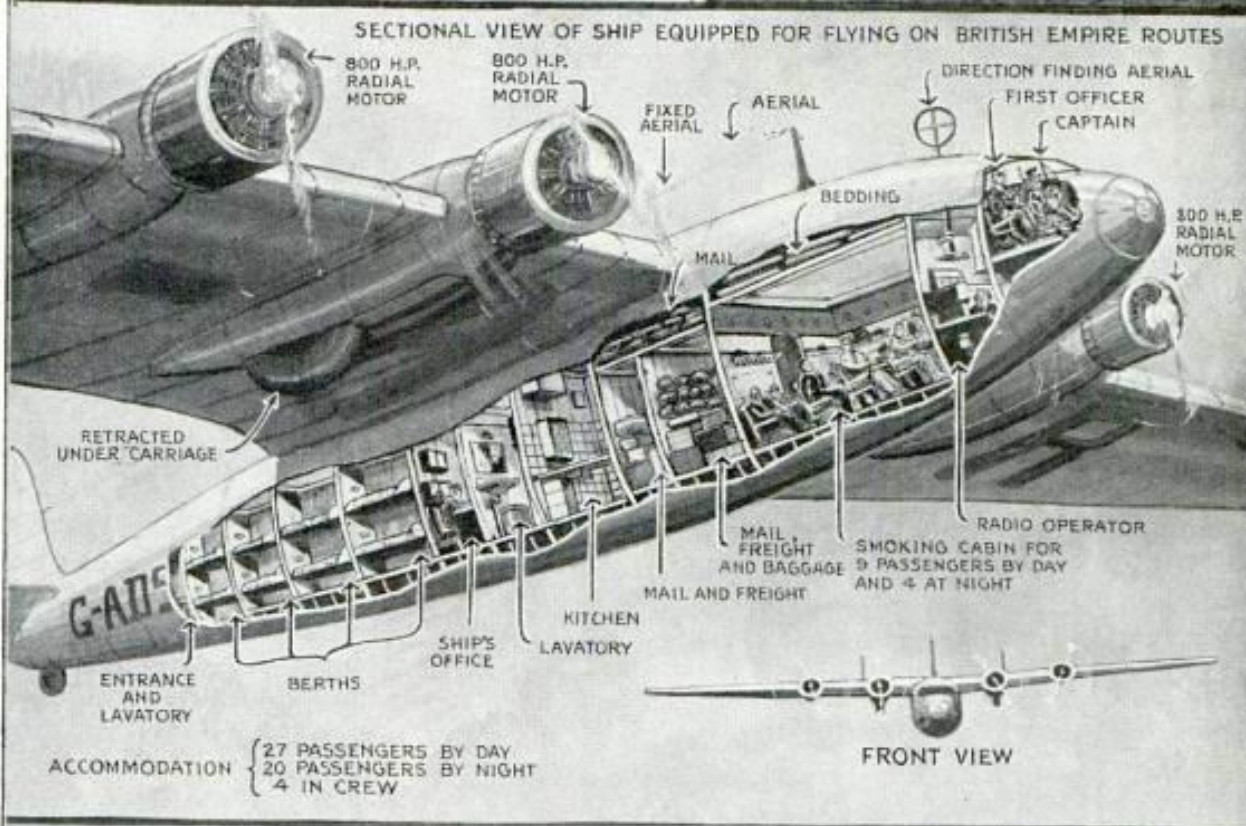
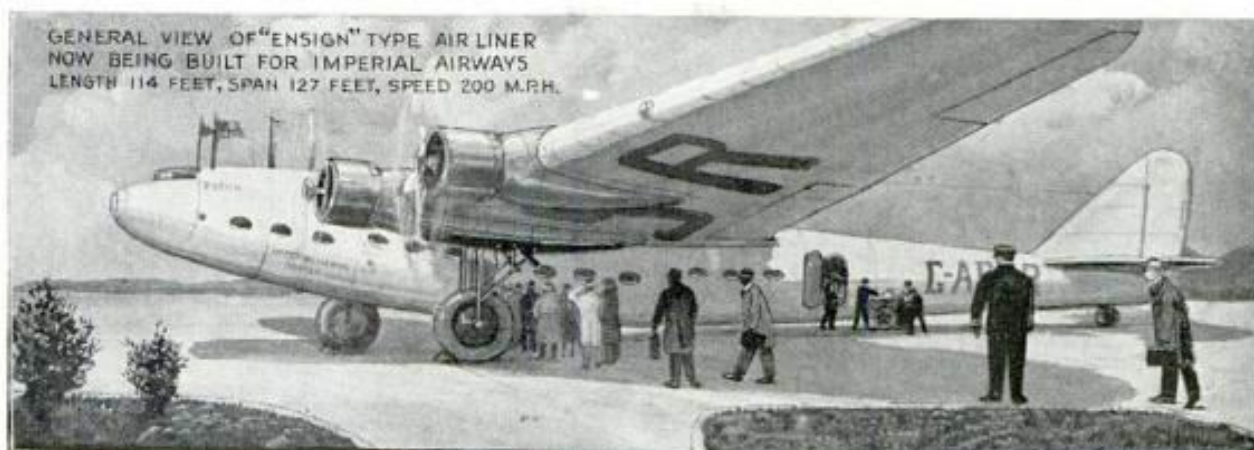
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Fleet of Big Air Liners to Fly British Routes



Top and bottom, giant land plane being constructed for Great Britain's European routes. Center, flying boat which will fly Empire air lanes. Forty ships of these two designs will be constructed.

Esq.
"Lemmer" Hollister
Roch. Ewell, Surrey
England

Science



THE SKY'S THE LIMIT

A radical new construction technique will bring a 2000-ft. building to the city where the skyscraper was born.

BY JIM WILSON

Scott Toberman

didn't set out to build the world's tallest building. Television made him do it. When TV stations in the Chicago area began looking for places to mount antennas to broadcast high-definition television signals, the president of European American Realty decided to top the development company's sleek new office building with a 450-ft. antenna, and add extra floors for transmission equipment. Named for its address, the 7 South Dearborn Building will now rise 108 stories above its snug 200-ft. lot at the corner of Dearborn and Madison. From the sky-scraping tip of its antennas to the sidewalk in the heart of Chicago's famous Loop, it will measure an astounding 2000 ft. When completed, perhaps as early as 2004, it will bring Chicago more than great TV reception. It will return the honor of being home to the world's tallest building to the city where the skyscraper was born.

"The building represents a number of firsts," says Richard F. Tomlinson II, the managing partner of the architectural firm of Skidmore, Owings & Merrill (SOM) who is in charge of the project. "It will be the tallest concrete element in the world ever constructed from the ground level. It will be the first building designed specifically to house facilities for the transmission of digital television."

Even though antennas are excluded from official building height calculations, 7 South Dearborn still measures up. From street level to its roofline at 1550 ft., it will look down on the 1483-ft. Petronas Towers in Kuala Lumpur, currently the

COVER STORY world's tallest buildings

(see "The World's Tallest Building," May 1996, page 78). "It's going to put Chicago back on the map," says city planning commission spokesperson Becky Carroll.

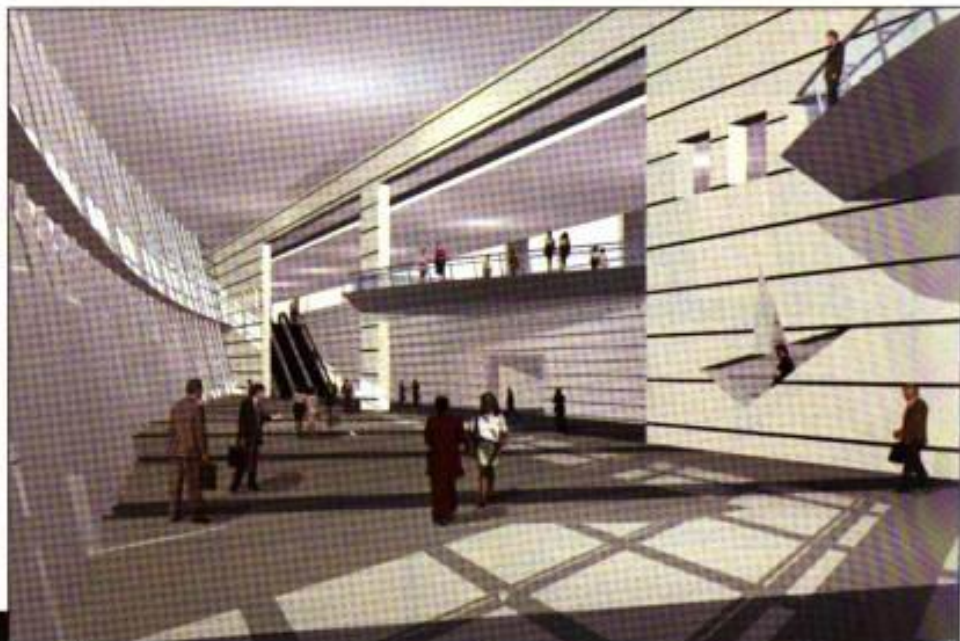
It's an architectural honor the Windy City first earned in 1885, when the Home Insurance Building reached the then-staggering height of 180 ft., opening the age of the skyscraper. During most of the 20th century, bragging rights for who's tallest were traded back and forth between Chicago and New York, until that sad day in 1996 when Petronas moved the honor across the Pacific, to Malaysia.

"7 South Dearborn is moving in an entirely new direction and to a stayed-mast structural system."

Rising Expectations

After the invention of a safe passenger elevator made it practical to build more than five stories high, architects adapted conventional techniques to accommodate additional floors, chiefly by making the walls below thicker. In this sense, tall buildings were simply ordinary buildings built tall. New York City's Flatiron Building broke the mold. It looked like a solid masonry structure, but it was actually an iron skeleton that transmitted forces into the earth. Called "curtain wall," it became the standard way to build.

Completion of the twin towers of New York City's World Trade Center in 1972 and 1973 marked the next



Floors that cantilever off the mast will produce large volumes of column-free space (above).

step in tall building evolution, with the first use of a "hollow tube" of closely spaced steel columns. It made for taller, stronger buildings, but tended also to clutter up the space inside. An SOM innovation, the bundled tube structural system, overcame these lim-

itations. It led to the current generation of SOM tall structures, including the Sears Tower and John Hancock Center, both in Chicago, and the Jin Mao Tower in Shanghai, the world's third tallest building.

Beyond The Tube

For 7 South Dearborn, SOM is moving in an entirely new direction and switching to a stayed-mast structural system, inspired by the mast on a racing yacht. The mast is a 4-ft. thick, 66 x 66-ft. reinforced con-

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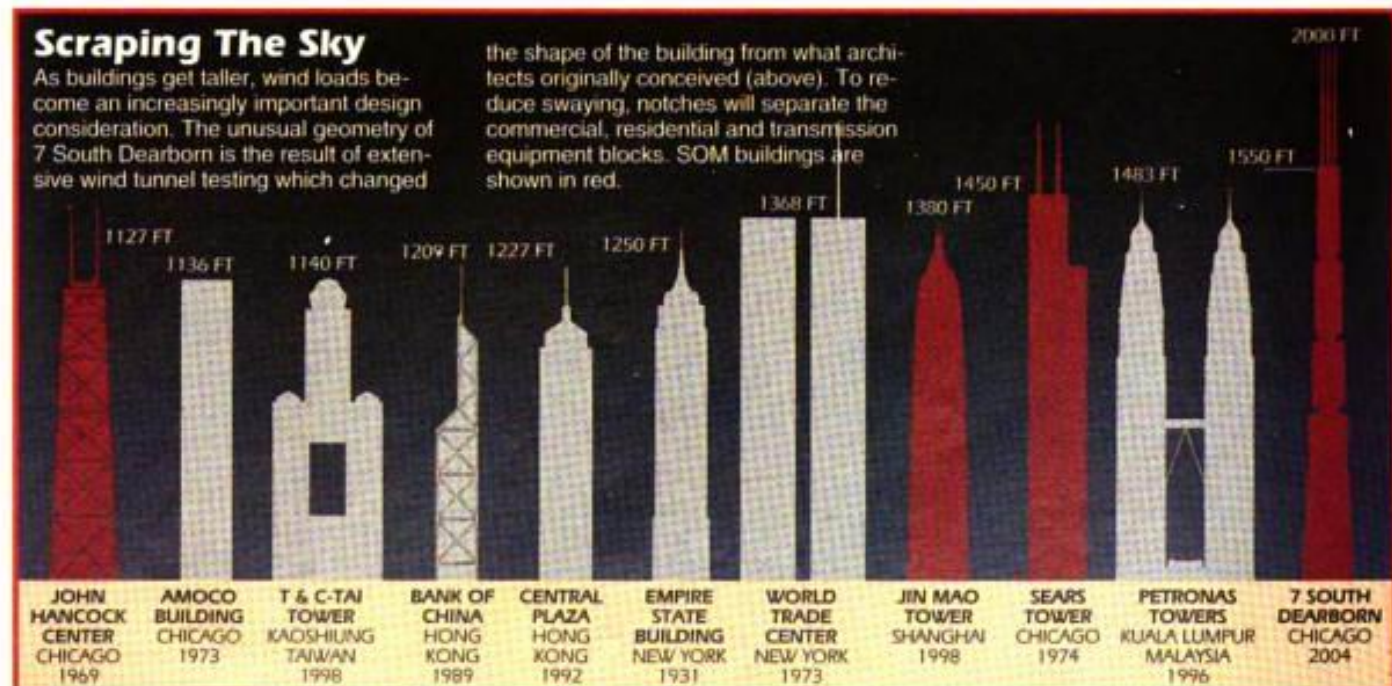
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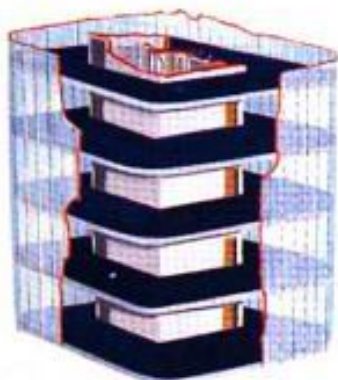
Scraping The Sky

As buildings get taller, wind loads become an increasingly important design consideration. The unusual geometry of 7 South Dearborn is the result of extensive wind tunnel testing which changed

the shape of the building from what architects originally conceived (above). To reduce swaying, notches will separate the commercial, residential and transmission equipment blocks. SOM buildings are shown in red.



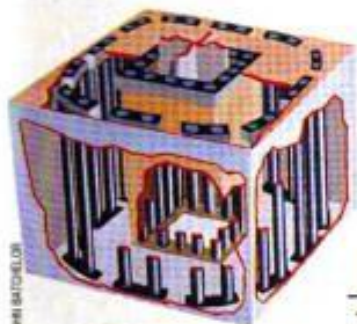
Inside 7 South Dearborn



Cantilevering the floors off the concrete core creates column-free space. Rounded corners, notches between blocks of floors and staggered setbacks as the building rises all will minimize the effect of wind.

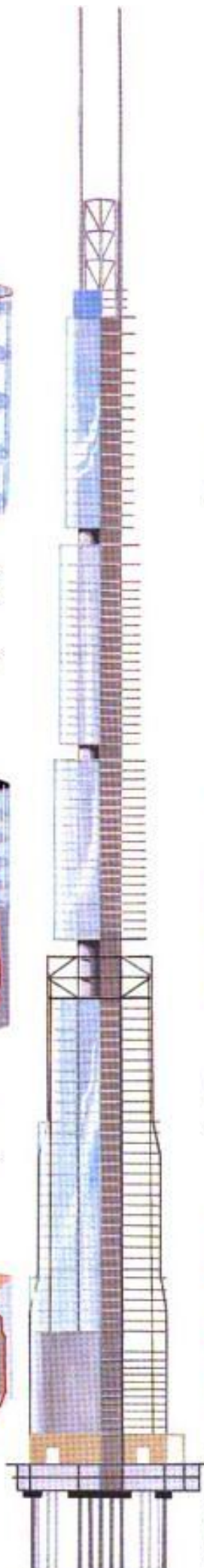


Placing the elevators and mechanical systems inside the concrete core will make the residential space quieter than in a traditional high-rise. The large amount of mass in the core dampens wind-induced sway.

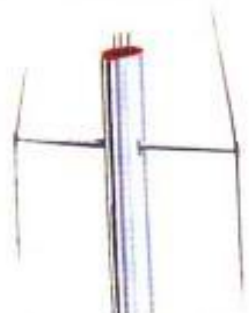


The 108-story structure will rest on a series of caissons drilled into the bedrock.

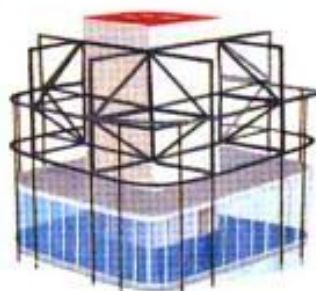
ILLUSTRATIONS BY JOHN BATHCHELOR



The block of 13 floors below the 450-ft. antenna will be used for HDTV equipment.



The structure was inspired by the mast of a racing yacht.



The concrete core, strong in compression, and steel columns, strong in tension, join at the spreaders.



The 1.9 million-sq.-ft. complex will include 13 floors of HDTV gear, 32 floors of offices, 40 floors of apartments and 11 floors of parking. The rest is shopping and commercial space.

crete core built atop caissons that reach down to the bedrock. It will contain the elevators and serve as the main support. Its rigidity will dampen wind-induced sway, and make the building quiet by isolating interior Sheetrock walls from the supporting structure.

On the lower levels there will be a limited number of widely spaced columns at the perimeter of the office block, essentially functioning as the mast rigging. There will be no interior columns within the office space. And, no columns at all in the upper portion of the mast, which houses the residential blocks, which cantilever outward. "This will provide 11 ft. of uninterrupted views in all directions," says SOM design partner Adrian Smith.

"Cantilevering the upper 57 floors achieves two primary structural engineering feats," explains Bill Baker, the SOM partner in charge of structural engineering. "It uses the gravity load of the floors to increase the strength of the concrete core," and it helps reduce wind loads.

Wind loads are one of the most critical factors that need to be taken into account in designing ultratall buildings. The distinctive notches that separate the business, residential and television equipment "blocks" will help to reduce wind loads that, during a peak once-in-50-years storm, could cause the top floors to sway as much as 2 ft. off center. The curved corners and progressive floor setbacks were developed in extensive wind tunnel testing, SOM structural engineer Robert Sinn tells *POPULAR MECHANICS*.

As we go to press, the half billion-dollar project has cleared its initial financial and governmental hurdles. Groundbreaking could happen later this year. Yet even before 7 South Dearborn officially earns its "world's tallest" title, the competition is already heating up to take it away. Rumors are flying of even larger buildings planned for Asia, once its flagging economy gets its second wind. Regardless of how long 7 South Dearborn is able to hold the title, it is destined to stay in the record books, as a technological giant step in skyscraper design. **PM**

COVER STORY

TITANS OF TRANSPORT

A new generation of oversize cargo planes—container ships with wings—promises to fast-forward the freight business.

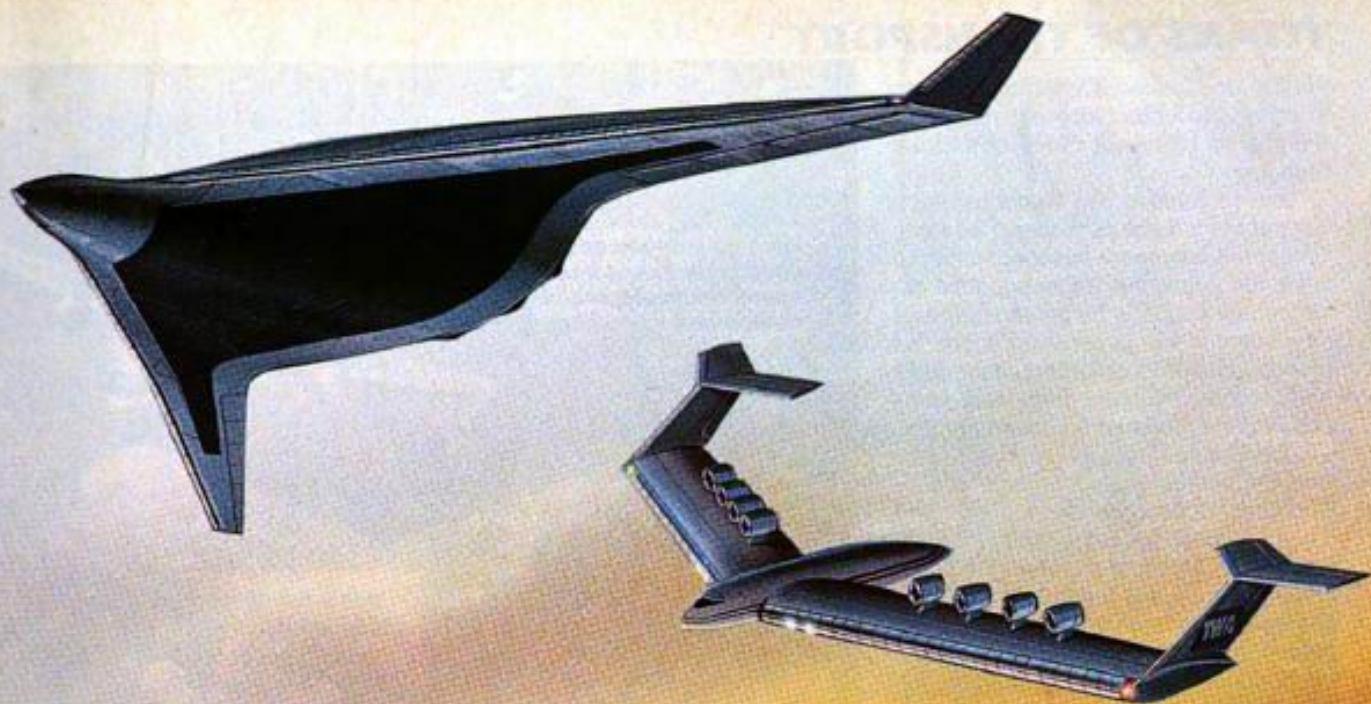
BY GREGORY T. POPE, Science/Technology Editor; PM Illustration by Craig Attebery



● March 19, 2015. Welcome to America's newest port. The thriving complex was once an abandoned military base. Today it pulses to the rhythm of import and export. Here, tractor-trailers stream off a freeway spur that feeds the port's material-handling zone. There, great robotic gantries hoist containers from the trucks and swing them into their next mode of transportation. Elsewhere, the big rigs themselves wheel right into gaping cargo holds, while others, brightly splashed with Asian and Cyrillic markings, rumble out.

The activity recalls the bustle of Amsterdam or New Orleans. But the ocean lies a thousand miles away. This port sprawls in the nation's heartland—it's an airport dedicated to freight. Those cargo holds yawn not from ships but from monster planes that touch down, discharge containers, load up, check out, refuel and roar off again to destinations abroad.

Could such a vision—the freight business lifted from the seas to the skies—come to pass? Transportation researchers are preparing for that possibility. After



Clockwise from top: McDonnell Douglas blended wing-body, Lockheed spanloader, Airbus Super Transporter, Lockheed Very Large Airplane and Molniya 1000 Heracles.

all, a similar revolution began 40 years ago, when the jet airliner lured long-distance travelers from the passenger ship. What the Boeing 707 did for trans-Atlantic passage, many argue, a new breed of all-cargo megajet could do for international trade—spur the growth of a huge new market drawn by speed and convenience.

Economics will determine how quickly and thoroughly this dream becomes reality. But America's aeronautics experts aren't waiting passively in the wings. At NASA's Langley Research Center, engi-

neers are beginning to hammer out technology requirements. Meanwhile, at NASA's behest, manufacturers are already sketching aircraft that would overshadow today's flying beast of burden, the Boeing 747-400F. And at the Massachusetts Institute of Technology, research is under way on the infrastructure—terminals, runways, cargo-handling gear—needed to usher in a new age of air freight.

At the center of all this brainstorming is the group of NASA-Langley aeronautical engineers led by

TITANS OF TRANSPORT

Shelby J. Morris. Right now, admits Morris, thinking about future air freighters prompts more questions than answers.

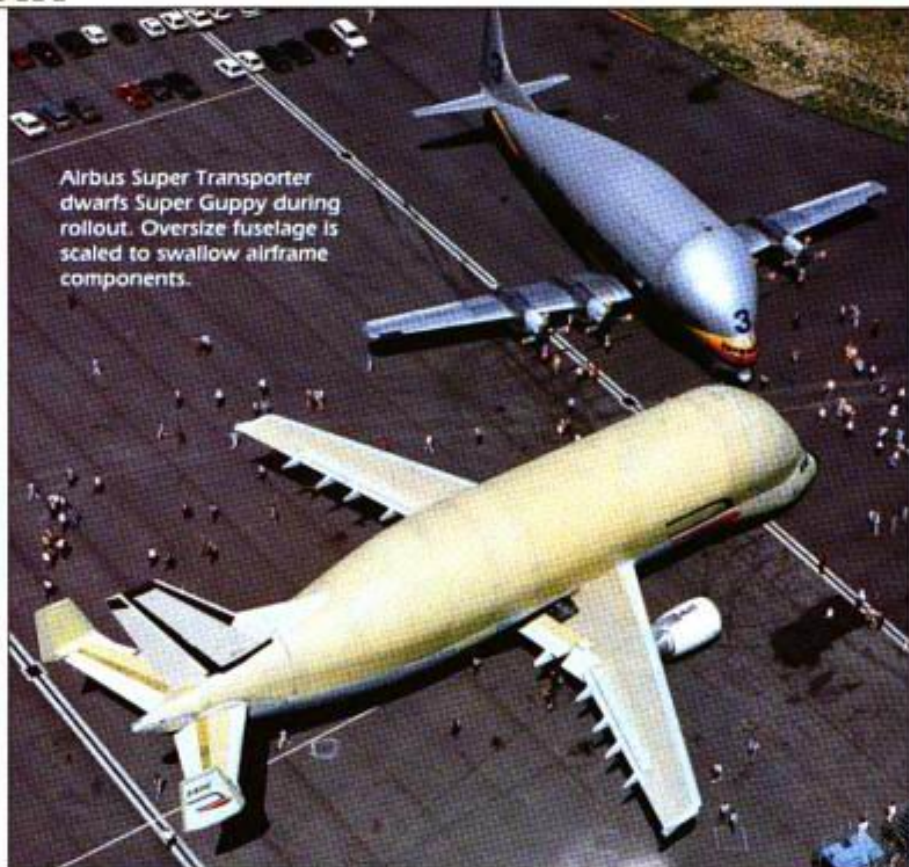
"We're looking, in a preliminary way, at very large airplanes," he says. "We think largeness has a virtue up to a certain point, but we're not sure exactly how large is large enough and how large is too large. And we're exploring the technologies associated with these airplanes, including radically different airframe shapes."

The blended wing-body (BWB) certainly qualifies as such. Conceived by McDonnell Douglas Aerospace (see Tech Update, page 16, April '94), its batlike silhouette emerged from a challenge, issued by NASA, to look beyond the winged-cylinder configuration that has typified transport aircraft since the 707.

The BWB began as a design for an 800-passenger, 7000-mile airliner. "But it turns out it works very well as a cargo airplane," says McDonnell Douglas's Bob Liebeck. "It has a large cabin that's very versatile in its layout. If you didn't need the cargo pressurized, you could build it very light." Liebeck envisions a cargo variant laid out like the passenger version: two decks stacked inboard with single decks out toward the wings.

In designing the aircraft, Liebeck and company assumed the technology of 2015—an all-composite structure, either three or four big ducted-fan engines, "fly-by-light" fiberoptic controls and the relaxed static stability seen today in the B-2 bomber. According to a McDonnell Douglas analysis, the BWB would outperform an equivalent conventional aircraft—such as a double-decker Boeing 747—that featured the same technology.

Even more radical is the spanloader, a concept that surfaced in the late 1970s when NASA last sponsored a major study of future cargo planes.



In this configuration, cargo takes up space inside the aircraft's gigantic wings. Spanloader anatomy minimizes the distance between aerodynamic lift forces and the payload to be lifted, thus reducing structural reinforcement and hence the airplane's weight. Lockheed Aeronautical Systems Co. has recently considered a spanloader sized to carry 600,000 pounds over 3000 miles.

Lockheed is also toying with a more traditional silhouette in a vehicle known simply as the Very Large Airplane. Something like a mammoth C-5 Galaxy, the aircraft could play three roles at once: cargo, passenger and military airlift. "If one thinks about multiple uses early enough in the de-

sign process," says Lockheed's Tony Hays, "there may be a way to satisfy all these requirements without significant compromise." This approach veers from the conventional route taken by Boeing, McDonnell Douglas and Airbus—each of which has plans for a superjumbo of at least 600 seats, an airliner that might later be pressed into freighter service.

Payload payoff

One thread common to the tailoring of these planes is their accommodation of intermodal cargo containers. Those are the standardized 8 x 8 x 20-ft. or 8 x 8 x 40-ft. steel boxes hauled by ship, train and truck alike. The Boeing 747-400F can swallow only 14 alu-



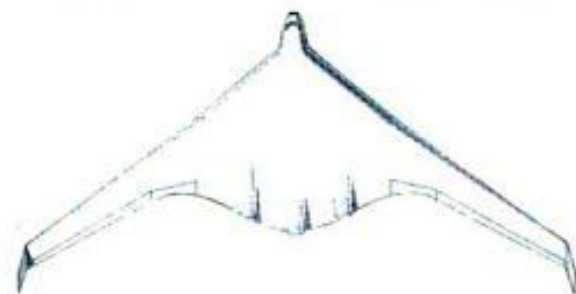
BOEING 747-400F

WINGSPAN: 213 FT.
LENGTH: 231 FT.
MAXIMUM PAYLOAD: 280,000 LB.



LOCKHEED VERY LARGE AIRPLANE

WINGSPAN: 281 FT.
LENGTH: 262 FT.
MAXIMUM PAYLOAD: 410,000 LB.



McDONNELL DOUGLAS BLENDED WING-BODY

WINGSPAN: 280 FT.
LENGTH: 172 FT.
MAXIMUM PAYLOAD: 300,000 LB.



Unusual silhouettes mark blended wing-body, shown above in original 4-engine configuration, and spanloader, shown below loading through wing.

minum versions of the 20-ft.-long containers, while a typical container ship can take on 4000. For the air-cargo market to support development of giant freighters, researchers believe, the planes must be optimized to handle intermodal containers.

Outsized consignments defy containerization, however. To get such shipments airborne calls for a special-purpose sky freighter. One, in fact, made its maiden flight last September. The Airbus Super Transporter (AST)—an A300 modified with a whaleback fuselage—offers a record 50,000 cu. ft. of main-deck cargo volume, more than either the Lockheed C-5 or the Antonov An-225. Airbus has planned a fleet of four ASTs, replacing the 40-year-old Super Guppies, to whisk aircraft-fuselage sections between assembly facilities in Europe.

Russia's Molniya Scientific and Industrial Enterprise also targets bulky payloads with its proposed Heracles heavy lifter. Three wings, two fuselages and six engines would create the world's strongest airplane—able to lift 992,060 pounds and roar skyward weighing nearly 1000 tons. A removable payload canister would nestle between the fuselages.



Landing trouble

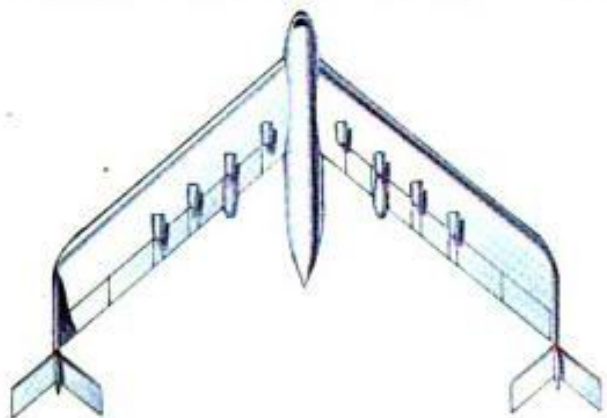
The sheer size of all these proposed aircraft raises questions. "It's going to be tough to get these very large airplanes into existing airports," says Robert Simpson, director of MIT's Flight Transportation Laboratory. "It's going to mean moving taxiways and tearing down buildings and folding wings. And the strength of the runways becomes a problem."

Simpson has aired a novel solution—landing amphibious freighters on pier-lined lakes. While this idea intrigues the NASA-Langley group, they point out complications from corrosion—and the fixed geography of lakes. Location of an air-freight port is critical to the concept. "The system wants

to go midcontinent to midcontinent," notes Simpson, "trying to save time and money by avoiding the train."

Time and money will ultimately dictate the success of the sky-freight revolution. Boeing predicts air cargo growing at a rate of 6.5% a year, which triples the tonnage by the year 2013. Already air transport attracts shippers for whom the added cost is outweighed by their cargoes' short-lived market value. These include garments, electronics and other items with fickle customers and fast-changing models. For these businesses, time is money, and time flies. So as industry's pace continues to gather speed, look for the titans of transport to deliver the goods.

FM



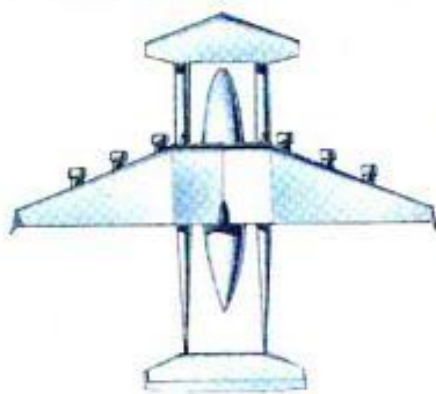
LOCKHEED SPANLOADER

WINGSPAN: 331 FT.
LENGTH: 256 FT.
MAXIMUM PAYLOAD: 600,000 LB.



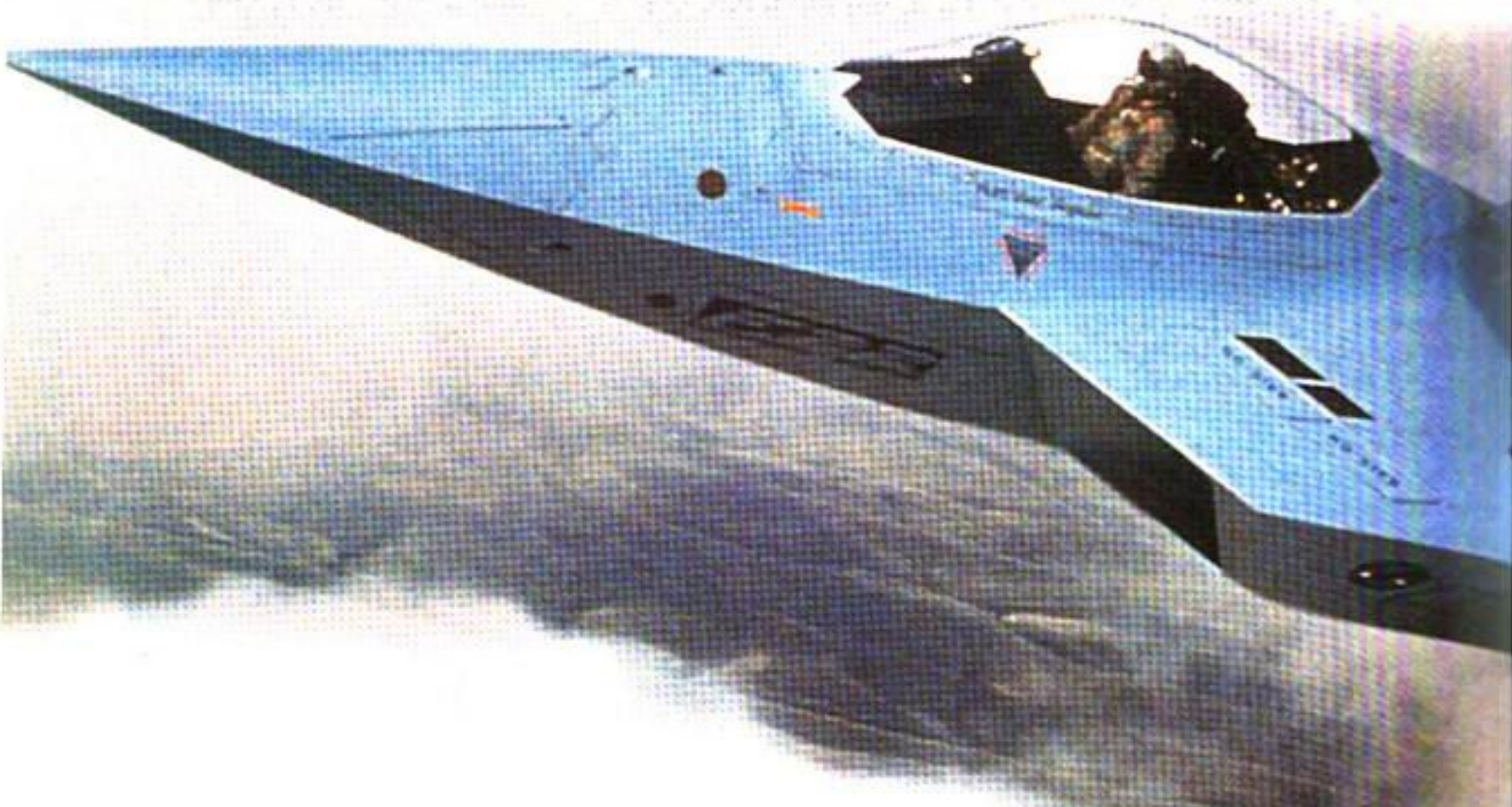
AIRBUS SUPER TRANSPORTER A300-600ST

WINGSPAN: 147 FT.
LENGTH: 184 FT.
MAXIMUM PAYLOAD: 100,309 LB.



MOLNIYA 1000 HERACLES

WINGSPAN: 295 FT.
LENGTH: 240 FT.
MAXIMUM PAYLOAD: 992,060 LB.



21ST CENTURY FIGHTER

The F-22 air superiority fighter pushes the envelopes of stealth and speed.

BY WILLIAM GARVEY

► They call it Raptor and it truly is the most fearsome bird in the sky. Its mission is to control the highest ground, the airspace above the battle area. It is a simple but effective strategy. The Air Force

COVER STORY

boasts that no U.S. ground soldier has been killed by enemy aircraft in more than 40 years, a period that includes the Vietnam War, invasions of Panama and Grenada, and Desert Storm.

Keeping hostile skies all-American has been the job of some noteworthy fighters, including the F-100 Super Sabre and F-4 Phantom. For the past 20 years the U.S. Air Force's alpha wolf has been the twin-engine F-15C Eagle air superiority fighter. Although the Eagle is superb at its work—F-15Cs shot down 32 enemy fighters in air-to-air combat during the Gulf War—foreign-

made fighters with equal or superior capabilities are becoming operational, as is a new generation of ultra-lethal, foreign-made missiles. Thus, the possibility exists that the bad guys could eventually outgun us.

"Americans don't have a God-given right to air dominance," says former Air Force Chief of Staff Gen. Ronald Fogleman. "Somebody's got to invest in it."

Proud Heritage

With continued, undisputed mastery of the skies in mind, the Air Force began developing a successor for the then-new F-15 back in the mid-1970s. Studies revealed that to dominate airspace in the 21st century, an aircraft would have to be very fast, agile, well-armed, and although the term was still classified, stealthy.

After considering six separate proposals, in 1986 the Air Force issued development contracts for two fighter



designs, the YF-22 (above) to be built by Lockheed in partnership with Boeing and General Dynamics, and the YF-23 from Northrop teamed with McDonnell Douglas. The service also ordered competing engines from General Electric and Pratt & Whitney.

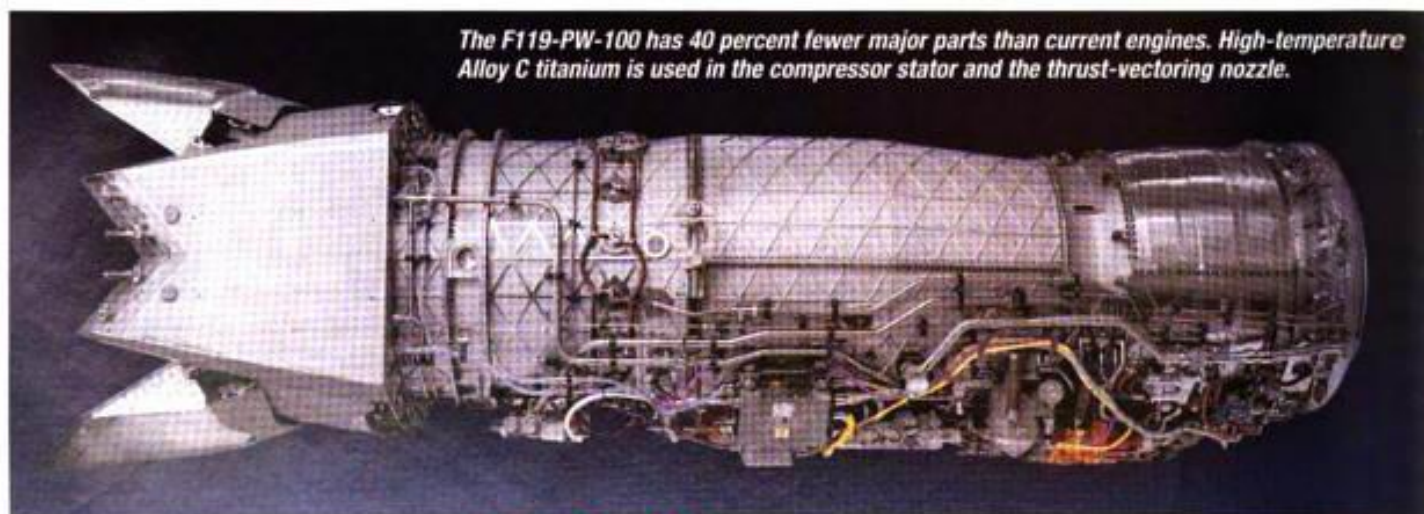
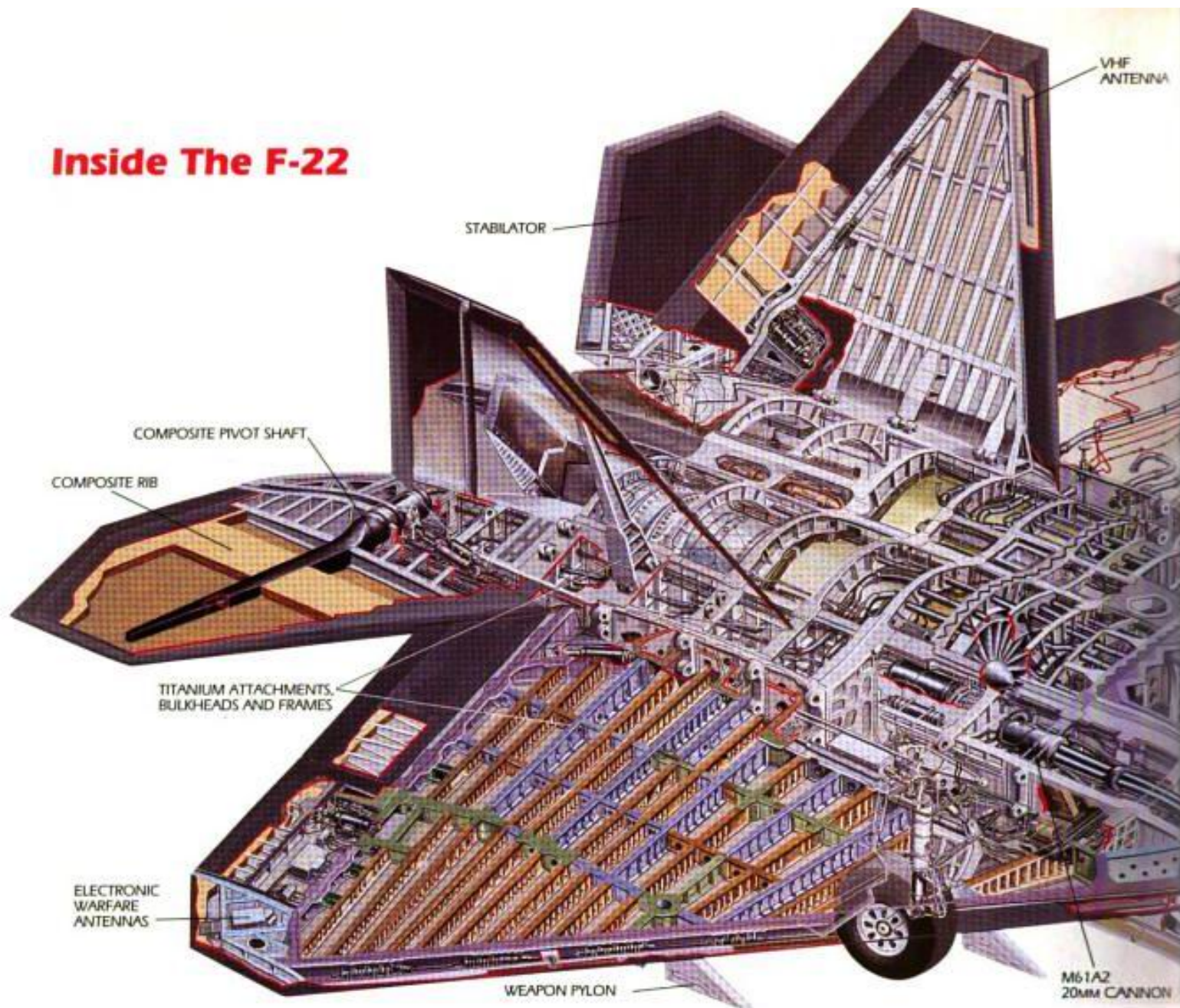
The competition to be chosen to build the service's Advanced Tactical Fighter was intense: The winner would receive contracts for up to 750 aircraft worth tens of billions of dollars. The stakes just don't get any higher. By 1990, the two prototypes were dogfighting for their futures in evaluation flights over Edwards Air Force Base in California. In April of the following year the Air Force selected as its winner the Lockheed/Boeing/General Dynamics design, powered by a pair of Pratt & Whitney F119-PW-100 engines. The YF-22 would become the F-22. It would not only be America's 21st century fighter, it would raise the technological bar

for all high-performance aircraft to follow.

Continued flight and wind-tunnel testing resulted in refinements to the design, and in December 1993 parts fabrication began for the first flying F-22. The division of work had Boeing handling software and avionics integration and building the aft fuselage and wings. Lockheed's Fort Worth division, which it acquired from General Dynamics in 1993, was responsible for the mid-fuselage and armament. And what was then Lockheed-Marietta, and is now Lockheed Martin, was charged with building the forward fuselage, vertical fins and stabilizers, and landing gear, and doing the final assembly.

On April 9, 1997, with flags aflutter, congressmen pontificating, workers cheering and salutes and smiles everywhere, the first true F-22 was unveiled in Lockheed Martin's Georgia assembly plant, while the walls reverberated with the strains of "The Spirit of America."

Inside The F-22



The F119-PW-100 has 40 percent fewer major parts than current engines. High-temperature Alloy C titanium is used in the compressor stator and the thrust-vectoring nozzle.

"This is a great day for America," Fogleman said. "We have no desire to control the world. We have an equally great desire to see that no one else controls the world."

The Raptor's mission is to see that no one does.

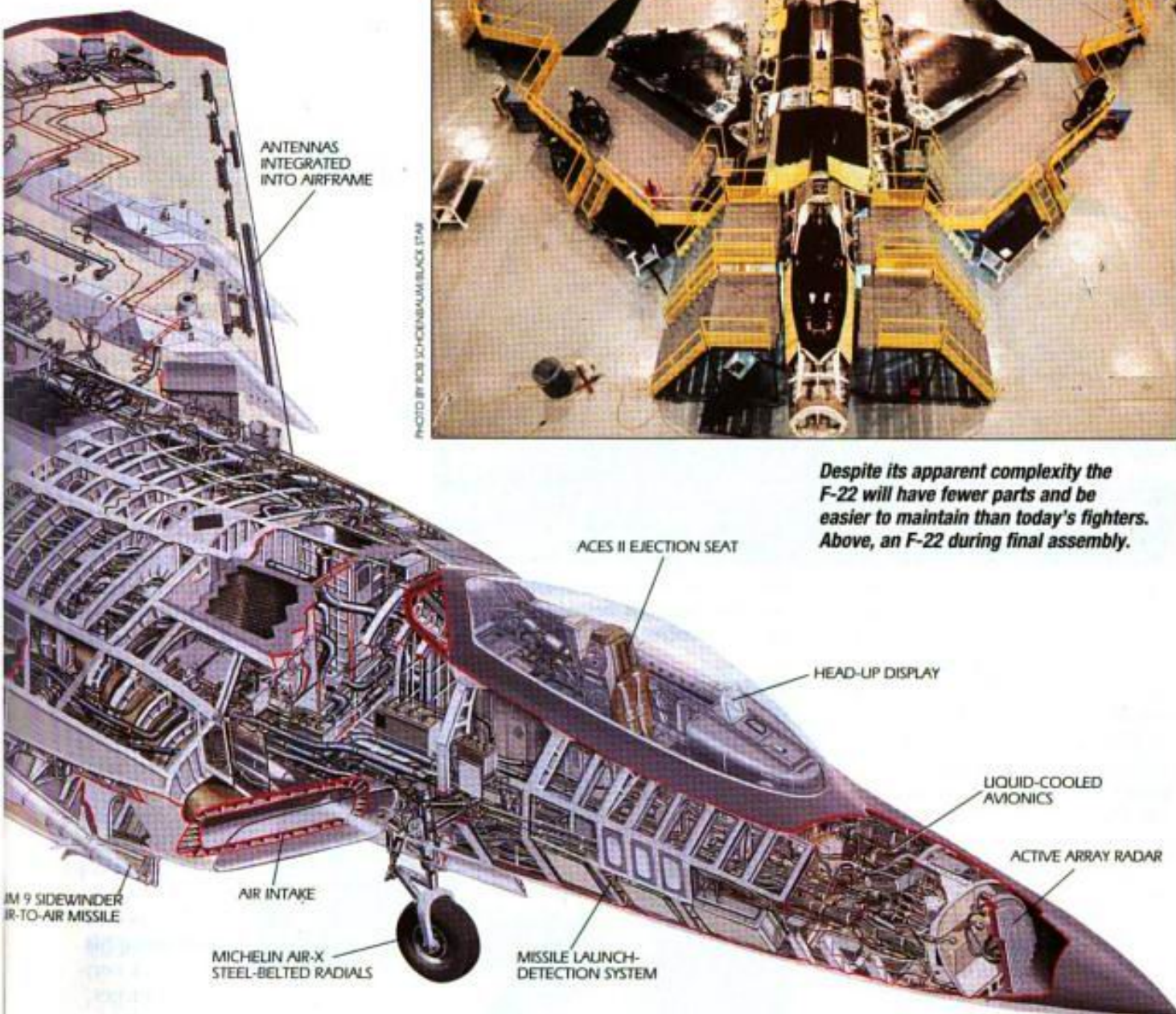
Into The Sky

The aircraft began flight trials in May of 1997. Eventually it could be joined by additional development and preproduction models, for a five-year program of flight and ground testing. Whether this amaz-

ing aircraft goes into full production remains an open question.

The Pentagon has already slashed costs in the F-22 program by slowing its development and reducing the planned fleet size to 438 aircraft. Still, with each aircraft valued at

"We have no desire to control the world. We have a great desire to see that no one else controls the world."



Despite its apparent complexity the F-22 will have fewer parts and be easier to maintain than today's fighters. Above, an F-22 during final assembly.

somewhere between \$70 million and a breathtaking \$198 million, depending on how costs are computed, the program is undeniably expensive—perhaps prohibitively so. Earlier this year, Congress pulled the plug on production money, but still allocated more than \$1 billion for continued development. So, as we go to press, the program continues to move forward.

The problem is that the airplane was supposed to trump the Soviets' next generation of weaponry. But now the Soviets are gone and Russia's military is barely able to put

down internal conflicts. Many in Washington question the need to build the F-22 at all. The Pentagon also wants to develop the single-seat F/A-18E and the two-seat F/A-18F maritime strike attack Super Hornet, plus the Joint Strike Fighter. Budget cutters say there's not enough money to go around.

If the original F-22 survives and the current schedule remains intact, production could begin within a year, with the first unit becoming operational as early as 2004. The last aircraft would be delivered to the Air Force in 2012.

Unbeatable Technology

Constructed of 15 tons (its exact weight is classified) of titanium, aluminum, thermoplastic composites, fiberoptic lines, silicon, rubber and glass molded into a twin-tailed package, the jet measures 62 ft. 1 in. long, 44 ft. 6 in. wide, and 16 ft. 5 in. tall. It is the most sophisticated aircraft ever to have lifted off a runway.

To build this 21st century wonder, the Air Force drew upon all the knowledge gained in developing the F-117A stealth fighter, B-2 stealth bomber and even the SR-71 spy plane. Thanks to shaping and mate-

DESIGN & ENGINEERING AWARDS 2000

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DECEMBER 1999

BEST
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FIGHTER FOR A NEW CENTURY

Inside
America's
New F-22
Fighter

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NOVEMBER 1999

**I DROVE
THE
INDY 500**
By Jay Leno

Popular Mechanics

FIGHTING SHIPS OF THE 21ST CENTURY

Radical Trimaran Hull
Kicks The Waves At
Speeds That Will
Revolutionize
Naval Warfare

CS GO SCI-FI
New Desktops
Sport Weird
Shapes And
Wild Colors

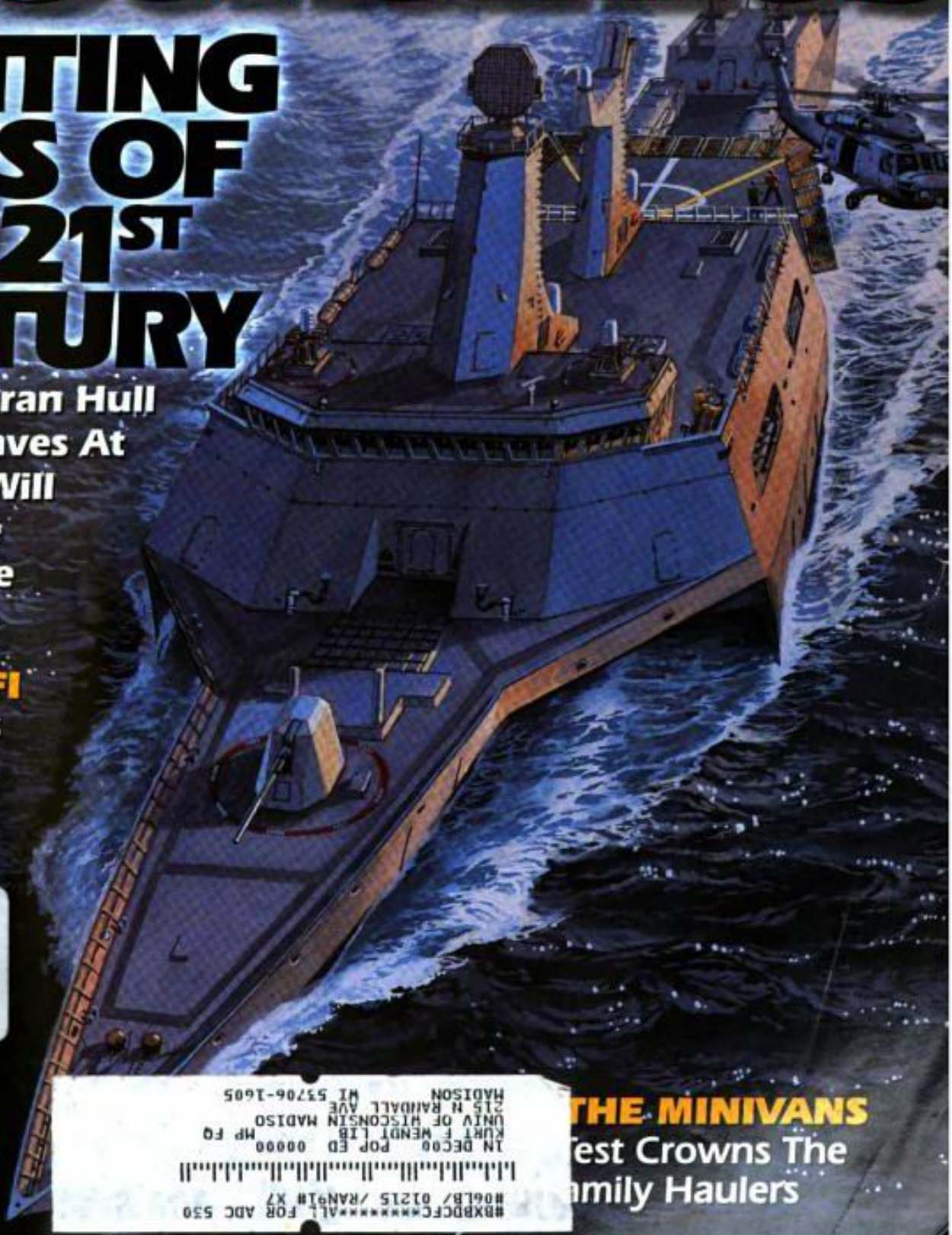
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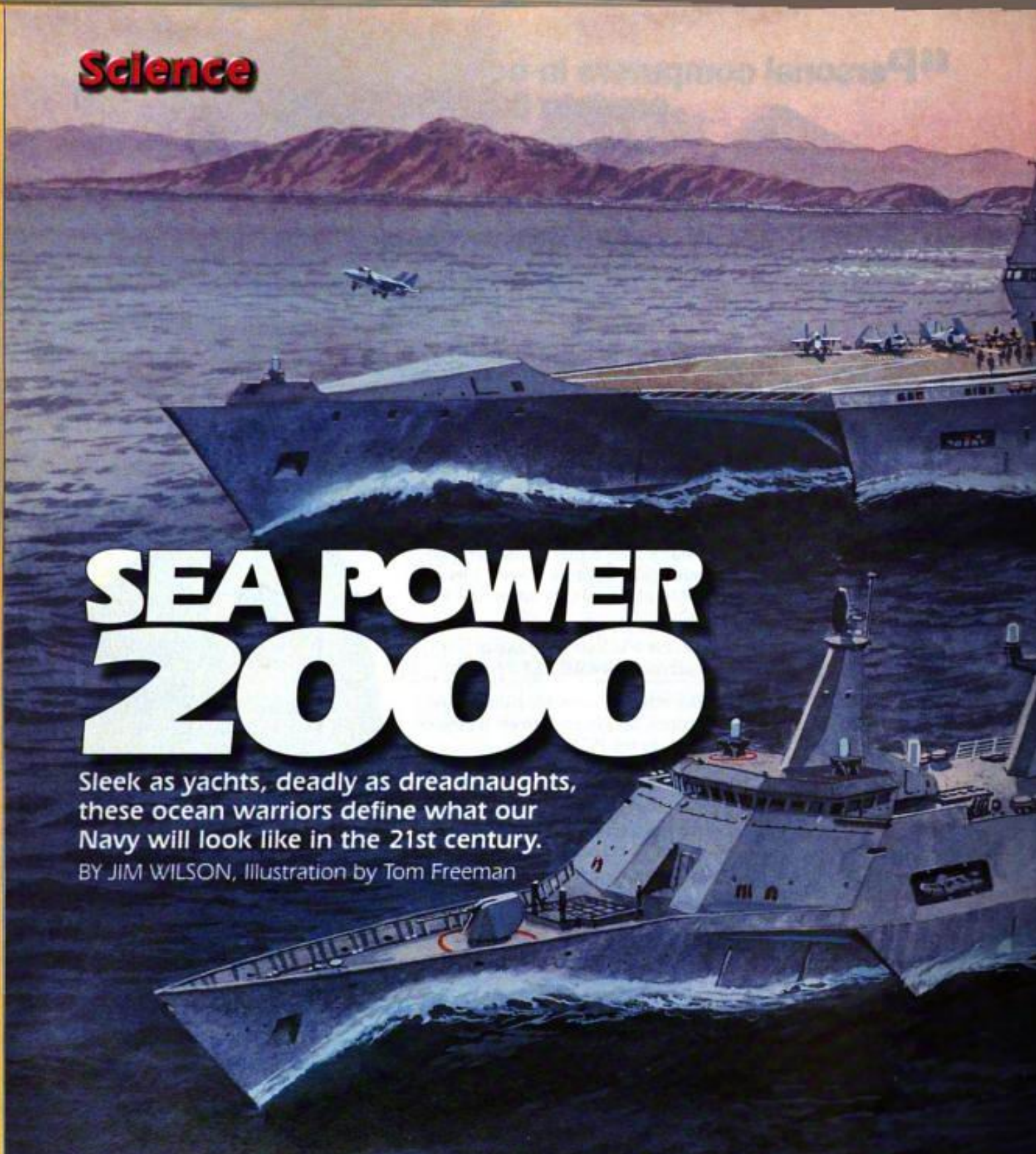


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THE MINIVANS
Best Crowns The
Family Haulers





SEA POWER 2000

Sleek as yachts, deadly as dreadnaughts, these ocean warriors define what our Navy will look like in the 21st century.

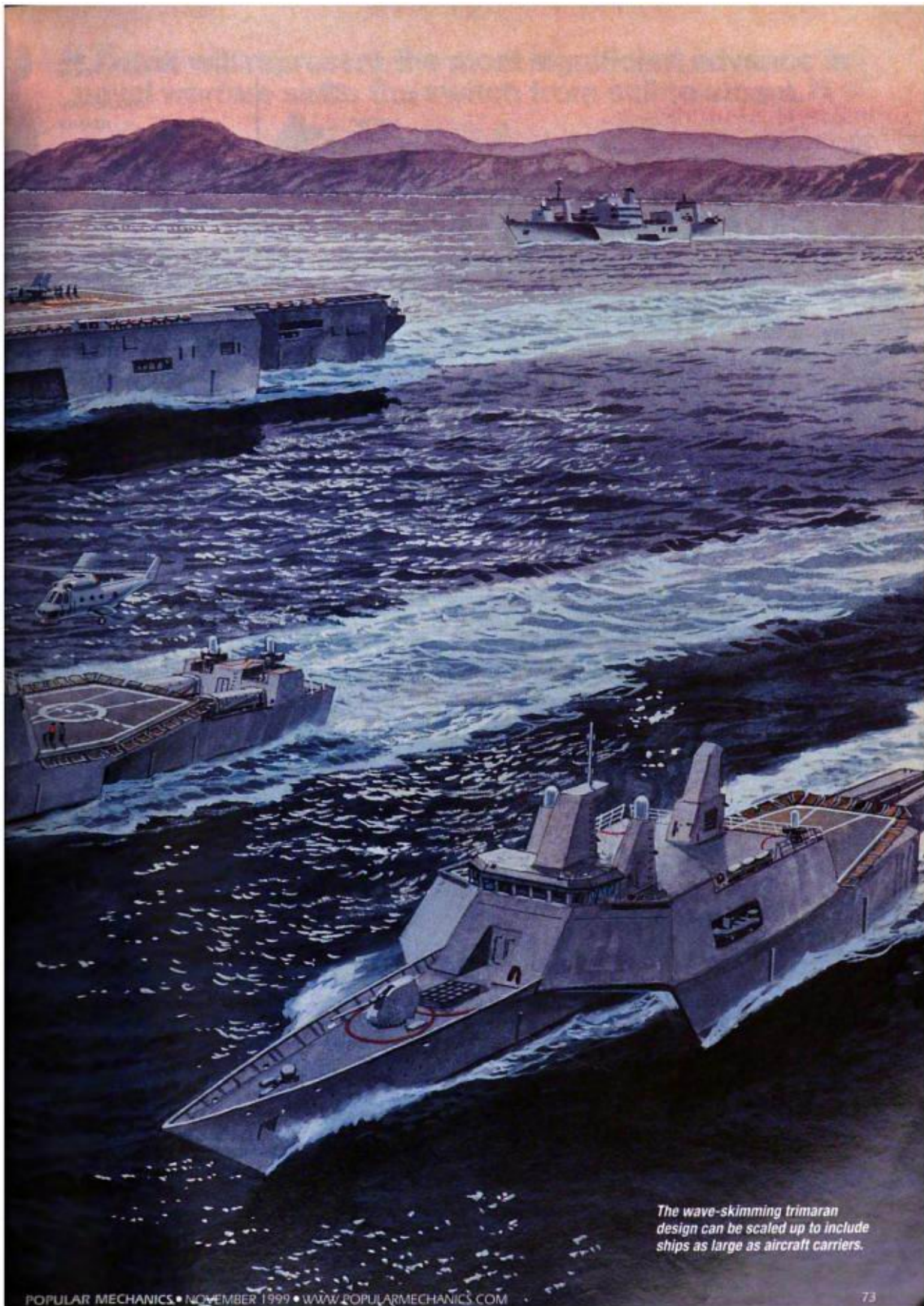
BY JIM WILSON, Illustration by Tom Freeman

▣ Shipbuilder Mike Carter

steps nimbly between two knee-high piles of half-inch steel plate. "Beautiful isn't it?" he asks, tracing a broad curve with his extended arm. "You don't get cuts like that with an acetylene torch." Fresh off a nearby plasma-arc cutting machine, the steel is so finely edged it almost appears polished. A dozen more stacks fill the football field-size workshop. It is easy to imagine we're standing inside a box filled with parts for a model boat kit, which in a manner of

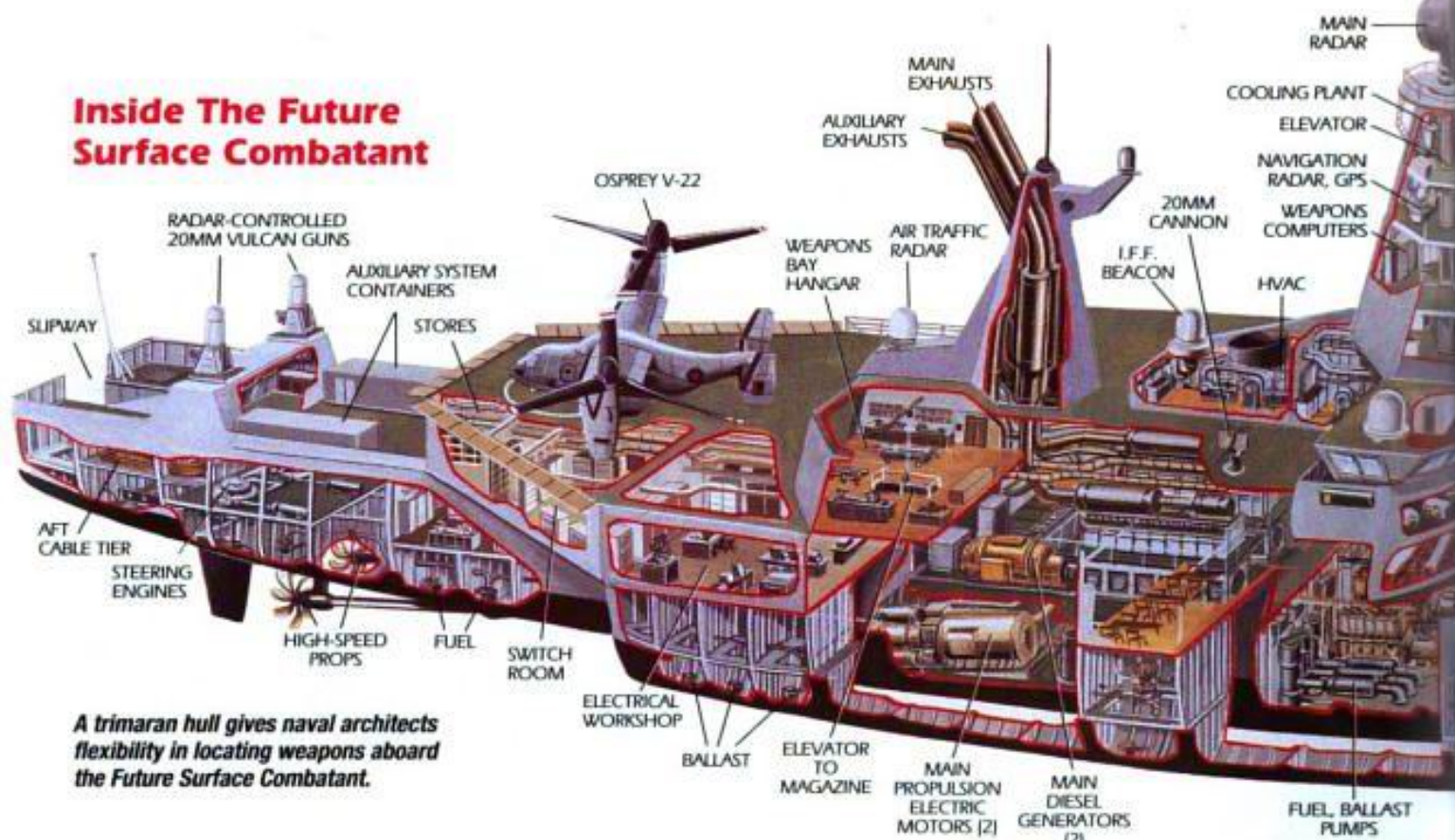
speaking, we are. POPULAR MECHANICS has been invited to the Vosper Thornycroft (VT) shipyard in Southampton, England, for an exclusive look at the construction of the *RV Triton*, the prototype for a new generation of warships: battle trimarans.

By next April, these precisely cut pieces will be welded into a finished ship measuring roughly 300 ft. long and about 66 ft. at the beam. Britain's Defence Evaluation and Research Agency (DERA) believes that the *Triton's* fast, fuel-efficient and highly stable three-hull design will represent the most significant advance in naval warfare since the switch from sail to steam.



The wave-skimming trimaran design can be scaled up to include ships as large as aircraft carriers.

Inside The Future Surface Combatant



A trimaran hull gives naval architects flexibility in locating weapons aboard the Future Surface Combatant.



Even with the first sea trials of this two-thirds-size demonstrator several months away, the Royal Navy is so convinced of the merits of the new design it is considering a full-size version of the *Triton* as a replacement for its 22- and 23-class frigates. DERA showed PM sketches for an entirely trimaran fleet, including aircraft carriers.

While the U.S. Navy isn't using Royal Navy superlatives just yet, it, too, is impressed. Much of the U.S. research program is classified, but the Navy has acknowledged that it

has signed a memorandum of understanding with DERA under which Uncle Sam will pay for a major portion of *Triton's* sea trials. The U.S. Coast Guard plans to evaluate a modified *Triton*-class craft as a replacement for Hamilton and Bear class cutters.

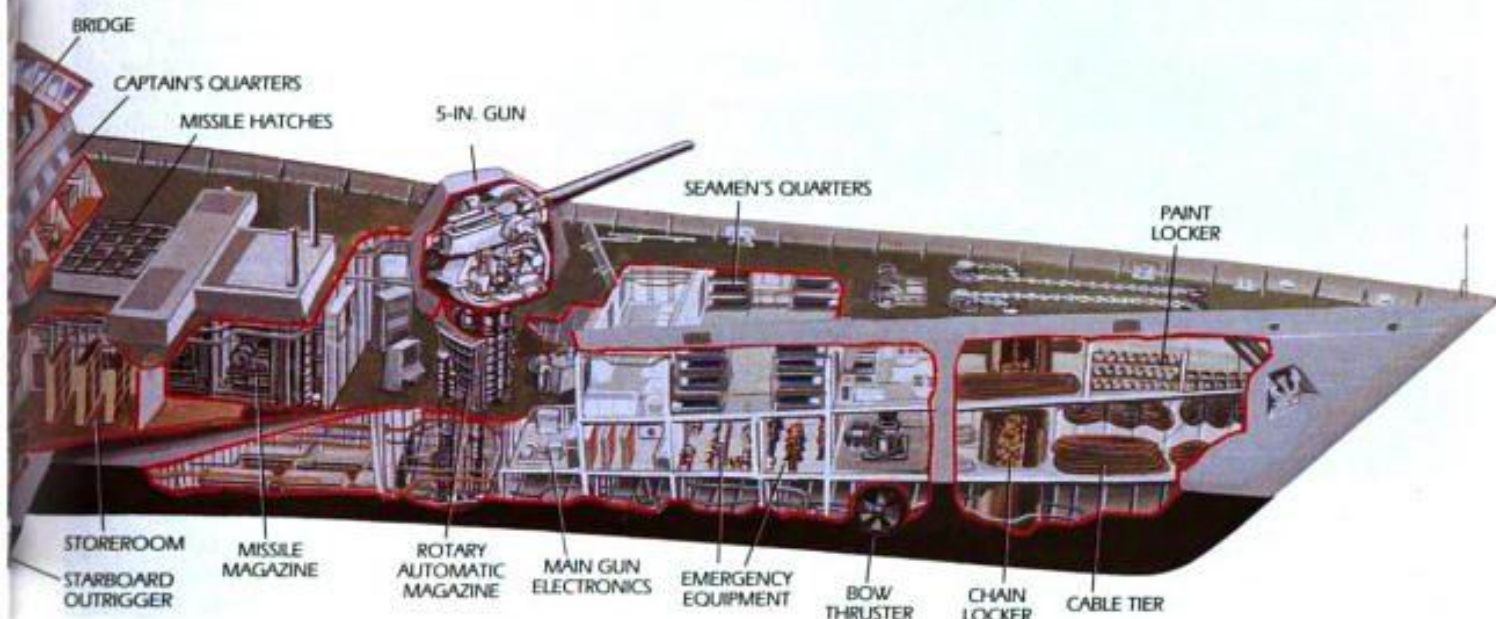
Three To One

"The possibility of using trimarans for warships was first studied by the Ministry of Defence sponsored professor at University College, London, in the late 1980s," explains

Chris Broadbent, the naval architect who is overseeing the project for DERA's Sea Systems Concepts and Integration Group in Fareham, England. Essentially, the students took an idea from the yachting community, the triple hull, and added the sort of armament required for a deep-water naval vessel. Impressed with what they saw, DERA and VT picked up the ball with follow-on research programs of their own.

Their computer models and water tank studies confirmed that a slender hull with outriggers could

"Triton will represent the most significant advance in naval warfare since the switch from sail to steam."



reduce drag by up to 20 percent compared to a single hull. The bottom line: "It will achieve 30 knots with about half the installed power required for the equivalent 83-meter monohull," says Broadbent. "The lower resistance will permit higher speeds to be achieved, or a reduced machinery fit leading to lower through-life costs."

The outriggers make the ship more stable, and give it a larger flight deck, which can be moved away from the stern and nearer amidships, allowing helicopters to operate under a wider range of sea conditions. Optional side-hull propulsion in the outriggers makes the ship more maneuverable. And if the ship does take a hit, the outriggers protect the inner hull, where the main powerplant is contained. "Survivability in general from weapons strikes will potentially be greatly improved," says Broadbent.

Different Needs

Although the British and the Americans are looking for different things in their next-generation warships, the trimaran design appears to please both. "The [British] Strategic Defence Review placed considerable emphasis on a fast response task group comprising larger, faster ro-ro [roll-on, roll-off]

vessels and ferries, which have evolved under commercial requirements," says Broadbent. "Ships transporting troops and equipment to a future area of conflict will be maintaining higher-than-convoy speeds in demanding sea states. It therefore becomes crucial for [combat] vessels to match that speed and sea-keeping ability."

The roles of Britain's first trimaran warships would include use as deterring patrols and in controlling the seas. In peacetime they would be used on antismuggling patrols, fisheries protection, search and rescue, disaster relief, research work and marine traffic control.

To perform these tasks, the Royal Navy envisions a faster, fully armed version of the *Triton*, which it calls the Future Surface Combatant (FSC). Capable of achieving speeds as high as 40 knots, the FSC would have a range of about 1500 nautical miles. Its crew would be small, consisting of nine officers, 21 senior ratings and 30 junior ratings. There would be additional room to berth 21 men undergoing sea training. The ship itself would be equipped for 21 days at sea. Or, as long as its 20 tons of fresh water and 90 tons of fuel oil held out.

The engines of the larger ship would be different from those on

Triton. One possible configuration, called the low installed power option, would use four marine diesel engines each rated at 3000 kw. Propulsion would be provided by two waterjets for cruising, each driven by a single diesel engine. One waterjet in the main hull would provide boost power driven by two diesel engines through a twin-input single-output gearbox.

Weapons on the FSC would include a medium-caliber gun, two small-caliber guns, two machine guns, medium-range surface-to-air missiles, surface-to-surface missiles and a torpedo launch system. To protect itself the FSC would be equipped with E/F, G or I band surveillance radar, an electronics warfare suite, and chaff and infrared decoy systems.

American Trimaran

The United States is less concerned about increasing the speed of military ships to escort fast merchant vessels. Its interests are more long range. "The U.S. in general is interested in innovative concepts. The trimaran concept has a lot of potential advantages," says Tom Cannon of the U.S. Naval Sea System Command, near Washington, D.C. He is the program manager for the joint U.S.-U.K. instrumented trimaran

"If you look at the way the U.S. Navy, all navies, are going, it is toward lower operating costs."



demonstrator. To see how well the idea works, the United States is placing 500 information-gathering sensors and a Trials Information System computer system aboard the *Triton*. During these trials, *Triton* will be manned by a commercial crew and research scientists.

"The idea is simply too good to pass by," says Cannon. "If you look at the way the U.S. Navy, all navies, are going, it is toward lower ship operating costs. If you can save

20 percent on fuel, you're really looking at something."

A second reason for the Navy's interest has to do with future propulsion systems. The Navy, like all branches of the service, is fighting a break-even battle with reenlistments. It sees the switch from steam systems, which are unique to each class of vessel, to electric propulsion, which could be used for all types of craft, as an important part of its serviceman-retention equa-

tion. In the future, a sailor trained to operate the propulsion system of a carrier could, for example, switch to a missile cruiser or possibly a submarine, something now difficult if not impossible. The ability to more easily change among ships over the course of a career is seen as a powerful incentive to reenlist.

Cannon believes that the earliest the new design might be applied is on the DD-21, an advanced land-attack destroyer, which is still in the early stages of development. Closely involved with this project, he rated the likelihood DD-21 would ride on a trimaran as a long shot.

Off The Shelf

Most everything aboard *Triton* will come off the shelves of commercial suppliers. Initially, VT's control subsidiary, VTC, has been given total responsibility for system design, integration and the procurement of propulsion machinery. Motors and controllers are being supplied by a European company, HMA of the Netherlands. The plant will consist of a pair of 2-megawatt diesel generators that feed a 3.5-megawatt electric motor that drives a single centerline shaft in the main hull.



The VP plasma-arc steel cutting system is so advanced, it even draws an ink-jet printed line showing where to weld.

Propellers in the side hulls will be driven by a pair of 350-kilowatt motors. The main generators will also energize the ship's auxiliary systems. The powerplant controllers and other systems will use View 2000, the Vosper multifunction workstation. Commercial, off-the-shelf open standard technology, it includes flat screens and zonal controllers dedicated to principal machinery areas including the main generators and motors, auxiliary



One possible configuration would be a vertical tube missile launcher that could pound targets hundreds of miles inland.

powerplant, damage control and propulsion control. A dual redundant fiberoptic ship databus will link the main workstations on the bridge with the machinery control room and the zone controllers.

"Besides its value as a trimaran demonstrator *Triton* will also provide the platform for the next step toward full electric propulsion," says Broadbent. To this end, *Triton* has been designed to allow for the installation of a permanent magnet main motor, a potential battery/fuel cell compartment and flight deck and engine room sites for future gas-turbine alternators.

In the United States, Newport News Shipbuilding (NNS), of Newport News, Va., and the General Dynamics (GD) Marine Propulsion Plant Team in Groton, Conn., are both developing integrated electric drive systems for the Navy.

The NNS system envisions a modular, 15 ft.-dia., 20-megawatt permanent magnet motor. It could be scaled up to 30 and 40 megawatts by adding modular magnets

to lengthen the rotor and corresponding segmented stator blocks. Each stator block would be mated to its own modular motor drive power controller. "This modular design makes the system easier and less expensive to maintain, and better able to survive battle damage," NSS manager Thomas Dade tells PM. The motor would be powered by a modified jet turbine engine, directly coupled to a generator with different voltage outputs for the powerplant and other ship service requirements, thus eliminating the need for both reduction gearing and transformers.

GD plans to employ radial air-gap permanent magnet motors driven by modular series-parallel motor drives. "These have been demonstrated at one-quarter scale, representing the most powerful permanent magnet motor system in the world," says GD's project manager, Ed Thaxton. The system

distributes medium voltage (5 to 15 kilovolts) power, using commercially derived vacuum switchgear that is one-half the size of commercial equipment. Power is supplied with a generator directly coupled to an aircraft-derived gas turbine. Ship service power would be supplied directly from the propulsion system.

Sea Trials

Regardless of their plans for future trimaran hulls, admirals around the world have their eyes on the *Triton*'s sea trials, which will begin next fall.

Rarely will the spotlight have shone more brightly on sea trials. Most modern weapons—small arms, artillery, tanks, even aircraft—have been the product of a slow but steady evolution. Not so with naval warfare where new types of ships—aircraft carriers and submarines to mention just two—routinely usher in new eras in sea power. Looking back from 50 years in the future, *Triton* just might be remembered as the 21st century ship that rendered 20th century fleets obsolete. **PM**

For More On Science

Check the Science channel on the PMZone Web site at <http://popularmechanics.com/popmech/sci/1HOMESCI.html>

Science

HUBBLE TROUBLE

Bad gyros force NASA to make an emergency visit to its high-flying space telescope.

BY STEFANO COLEDAN, Illustration by Jeff Mangiat

For the third time since its

1990 launch, the Hubble Space Telescope is getting a tuneup. Only this time, NASA is rushing a team of mechanics on a repair mission into space eight months earlier than planned. Three of the six gyroscopes that Hubble uses to orient and point itself in space have failed. It's now working with the minimum number required to make observations. If another gyroscope

ASTRONOMY

were to break, the telescope would go into a so-called safe mode—in essence, all science would grind to a halt. NASA isn't formally calling this an emergency, yet it has never organized a shuttle mission so fast. In mid-October, *Discovery* and a seven-member crew are scheduled to carry out part of a mission originally scheduled for June 2000.

"Hubble is the crown jewel of NASA's space observatories," says Ed Weiler, head of the space agency's science program. "It's serious to scientists. People have gotten used to seeing the results on a monthly and weekly basis." One functioning gyroscope would be enough for Hubble to get by in its 370-mile-high orbit

while awaiting repairs. But with astronomical observation time already at a premium, NASA wants to minimize the chance of interruptions in the \$2 billion telescope's heavy workload.

Four Spacewalkers

After getting into orbit, the pilots will maneuver the shuttle for a rendezvous with Hubble. Another astronaut will move the robot arm to grapple the telescope and then ease it down and place it onto a specially designed workbench inside *Discovery*'s cargo bay.

The main goal of four spacewalkers is to replace the three faulty gyroscopes, and the three that are still working—with six improved units. Three or four spacewalks, astronauts will have to remove screws and perform other delicate operations while wearing stiff pressurized gloves.

After replacing the gyroscopes, astronauts will change Hubble's guidance sensor and install a transmitter, a computer, and a solid-state data recorder to better handle his

volumes of scientific data. The new computer is designed to lower costs by reducing the need to send frequent software upgrades. The transmitter will replace a faulty spare unit. Finally, the repair crew will patch the telescope's thermal insulation, deteriorated by the harsh environment of space.

Although the STS-103 mission is scheduled to last nine days, it shouldn't be as complicated as the first Hubble repair flight in 1993. Then, astronauts had to install special lenses to correct the vision of the telescope's infamous primary mirror.

The work took a record five spacewalks, totaling more than 35 hours.

For the next

Astronauts have been working 10-hour days since March to prepare for their maintenance visit to the Hubble Space Telescope, which has lost the use of three of its six gyroscopes.

Components being replaced

1. NEWARKED COMPUTER
2. BATTERY CONNECTORS
3. SOLID STATE RECORDER
4. FIVE-BAND TRANSMITTER
5. GYROSCOPES

ON OPPOSITE SIDE:

FINE GUIDANCE SENSOR
AND THERMAL BLANKETS

flight, NASA has picked seven crew members with extensive space experience. The four spacewalkers have been training since August 1998. "The original service mission would have been very full," says mission commander Curtis Brown. "Six [spacewalks] had been planned, and they were packed." Splitting the mission in two has made it a little easier for the crew, he says.

A mission in early 2001 will do solar panel and infrared camera maintenance.

The mission scheduled to fly this month will cost NASA an extra \$125 million. The current plans are to fly a final maintenance flight in 2003. A replacement for the telescope will not be available until 2007 or 2008, Weiler says.

If all goes as well as NASA hopes, a space shuttle mission will bring the Hubble Space Telescope back to Earth around 2010, two decades after it first opened our eyes to the distant wonders of the universe.

PM

For More On Science

Check the Science channel on the PMZone Web site at <http://popularmechanics.com/popmech/sci/1HOMESCI.html>

SEA LAUNCH

The ultimate water rocket opens the next chapter in space exploration.

BY JIM WILSON

► Russian rocket

scientists don't count backward. They simply warn you to duck and cover, then methodically continue setting the match to their simple but reliable kerosene and liquid oxygen candles. This time the announcement is a purely symbolic gesture. There isn't a human being within 3 miles of the launch pad. And a computer has been minding the countdown for the past 4 hours and 59 minutes. Yet, even without the narration tension in the command center spools up. If a NASA or Air Force rocket becomes an expensive Roman candle, everyone still has a job the next morning. Sea Launch is a private venture. If it fails, a lot of people could be pounding the pavement.

A spray of flames reminiscent of a Fourth of July sparkler bubbles from beneath the million-pound rocket. Three miles of calm Pacific Ocean between the Odyssey launch pad and the control room inside the 28,000-ton *Sea Launch Commander* delay and then deaden the roar. Two heartbeats later, the 200-ft. rocket begins to rise into the equatorial afternoon. A camera captures a magnificent image of the Sea Launch Rocket

COVER STORY

arcuing eastward toward billowing fair weather clouds. It will take several weeks for a detailed analysis of the megabytes of information flowing into the command ship's computer to confirm what the members of the launch crew can feel in their bones. "We are now ready to begin full-scale service, as a proven and cost-effective commercial satellite launch service," says a triumphant Allen B. Ashby, president of Sea Launch. It is a very elegant way



Launching from the equator provides a jumpstart to geostationary orbit. Opposite, a Sea Launch rocket lifts off on its perfect maiden flight.

of saying that Sea Launch is about to become the Kmart of the commercial launching business.

Cheap Space

Sea Launch hopes to become the leader of the work-a-day world of commercial space. It involves heavy lifting in the most basic sense of the term: parking 8800- to 11,000-pound telecommunications satellites on 22,300-mile-high orbits where they can beam television programs and Internet downloads to millions of pizza-pan size "Earth stations."

To reach parking slots on the highest frontier, Sea Launch does exactly what its name suggests: It launches commercial space payloads at sea. Given the complexity



"Our equatorial launch site provides the most direct route to geostationary orbit."

of transporting, erecting and fueling a million-pound rocket this might not at first seem like a terribly sensible idea. Until you remember that the Earth is round. For the same reason that a speck of dust on the rim of a record moves faster than a speck near the hole, an equatorial location provides a fuel-saving boost. "Our equatorial launch site provides the most direct route to geostationary orbit," explains Ashby. To take advantage of the physics, Sea Launch conducts its operation 1400 miles southeast of Hawaii, on the equator, at 154° west longitude.

Sea Launch's biggest cost saving, however, comes from using automation instead of people. "Our marine operations reduce launch infrastructure, minimizing operational costs," explains Ashby. Land-based launch sites, most of which were originally military test ranges in the 1950s, are labor intensive, employing thousands. Sea Launch operates with a fraction of their number. Its 213-ft.-tall catamaran hull launch platform houses 70, the control ship another 240.

A World Of Parts

Sea Launch is as multinational as a business venture gets. Legally it is not an American business at all, but a corporation organized in the Cay-



man Islands. Its principal owners were some of the prime contractors for Cold War adversaries. Seattle-based Boeing owns 40 percent of the venture. Beyond being responsible for making sure that all of the pieces fit, Boeing operates the Sea Launch home port in Long Beach, Calif. It also built the payload fairings that protect satellites during their ride into space. Kvaerner Maritime of Oslo, Norway, owns 20 percent. It constructed *Odyssey*, the

435 x 213-ft. self-propelled launch platform, by converting a North Sea oil platform. It also built *Sea Launch Commander*, the 650-ft.-long mission control ship at its shipyard in Glasgow, Scotland. Both are registered in Monrovia.

Two former members of the Soviet Union built the Sea Launch Rocket. Its first two stages are the Zenit 3SL rocket, a civilian version of the nuke-hurling SS-18 ICBM built for the former Soviet Union by Yuzh-



Sea Launch Commander can take up to three rockets at a time to the Odyssey, a converted self-propelled oil rig.



LOADING SYSTEM

ASSEMBLY AND COMMAND SHIP

STEP 1: ROCKET ASSEMBLED AND TRANSPORTED TO LAUNCH SITE ON BOARD COMMAND SHIP

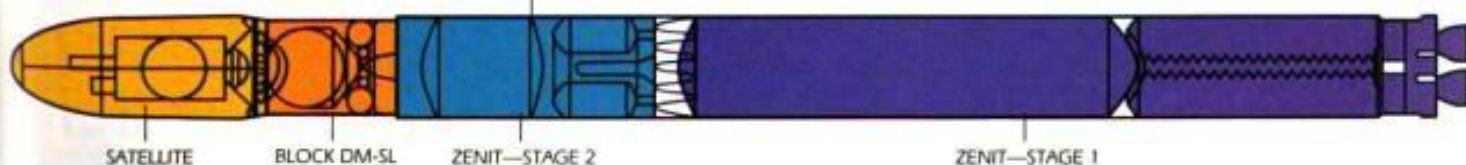
STEP 2: ROCKET TRANSFERRED TO LAUNCH PLATFORM

LAUNCH PLATFORM

STEP 3: ROCKET ELEVATED TO HANGAR DECK

STEP 4: ROCKET ROLLED OUT AND LIFTED INTO LAUNCH POSITION

THE SEA LAUNCH ROCKET



noye of the Ukraine. If its 15 percent stake in Sea Launch isn't enough to make Karl Marx revolve in his grave, the 25 percent owned by Moscow's RSC Energia, which provides the Block DM-SL third stage, certainly must be. The money for the half-billion-dollar project is coming from a consortium of 14 multinational banks. "Literally thousands of people in Russia, Ukraine, Norway, Scotland and the United States have been working for more than three years, making Sea Launch one of the world's leading examples of international cooperation in space," says Ashby. At one point last year the U.S. State Department thought there was a bit too much cooperation. It briefly suspended a Boeing Sea Launch export license: It was dissatisfied because too much controlled—but not classified—rocketry data was being shared with interna-

tional partners. The two sides eventually worked their problems out.

Cheap Launches

Sea Launch has no intention of being similarly compromising with its land-based launch services competitors. Its basic strategy is to undercut its competition with automation. Almost every part of the launch preparation that can be automated has been. "Sea Launch receives satellites at the home port facility in Long Beach," a company executive explains. After fueling and encapsulation in the payload processing facility, the rocket is transferred to the *Sea Launch Commander* assembly and command ship. The *Odyssey* receives the rocket about 27 hours before launch, and hoists it to its erect

position. Propellant chilldown begins at launch minus 4 hours and 20 minutes. Workers leave the platform as automated fueling begins. Seventeen minutes before liftoff, the transporter arm that righted the rocket on its pad is withdrawn. For the last 5 hours and through the 1-hour trip into space the launch crew essentially watches meters.

Originally, Sea Launch's maiden flight was to put a Hughes HS 702 communications satellite on a geostationary transfer orbit. Designated *Galaxy XI*, it was to become part of the PanAmSat network. The deal fell through, so on March 27, a simulated payload was launched instead. The next launch, which is scheduled for this month, will carry a Hughes satellite for a yet-unidentified customer. With 15 more customers waiting in line, Sea Launch truly is off to a rocketing start.

For More On Science

Check the Science channel on the PMZone Web site at <http://popularmechanics.com/popmech/sci/1HOMESCI.html>

Technology

Watch

Aviation • Computers • Energy
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Patriots Aim At Cruise Missiles

A modern variation of the balloons used to direct Civil War artillery fire could protect American forces from the greatest battlefield threat of the 21st century: cruise missiles.

The Joint Land Attack Cruise Missile Defense Elevated Netted Sensor (JLENS) system puts long-

range and attack radars on a pair of blimp-shaped helium- and air-

filled structures called aerostats. Tethers anchor the aerostats and hold



November Highlights

Flying Bunks—Elevating seats give long-haul passengers a good night's sleep.

■ **Park Anywhere**—Unusual cube-shaped car turns wasted space into parking space.

■ **Soviet Secrets**—Defense Intelligence Agency declassifies its archive of weapons artwork.

power cables and datalinks to a mobile command post.

After the 360° surveillance radar identifies a target that would otherwise be obscured by terrain, the attack radar takes over. It directs a Patriot missile to an interception point that, ideally, causes debris to fall over the launcher's own forces.

JLENS shined at this summer's Roving Sands exercise, warning "friendly" forces of incoming cruise missiles 10 minutes before they could be spotted on ground-based radar.

Editor: Jim Wilson
Reporters: Stefano Coledan, Steve
Ditka, Paul Eisenstein, Mike Fillon,
Mike Lamm, Barry Rosenberg.

Technology Watch

Aviation • Computers • Energy
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Reeling In Dead Satellites

A practical solution to the growing space-junk problem could literally be on-line. Tethers Unlimited wants to keep dead satellites from cluttering up low-Earth orbit by using its Terminator Tethers to drag potentially lethal space trash to a fiery death.

During a satellite's working life several miles of braided aluminum tether would be stowed on a reel.

When the satellite retired the reel would lower the weighted tether. Because the satellite and tether would be moving across the Earth's magnet-

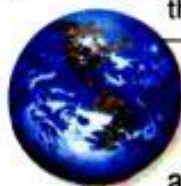
ic field, a voltage would be induced along the tether, causing a current to flow. At the ends of the tether, this current would be transmitted to the thin

space plasma present in low-Earth orbit, says Robert Hoyt, of the Seattle company (206-306-0400).

"The current flowing through the tether would cause power to be dissipated in the resistance of the metal in the tether," Hoyt says. "This power has to come from somewhere, and it comes out of the orbital energy of the satellite."

After a few months the satellite would fall below orbital speed and burn in the upper atmosphere.

A series of five tests aboard Russian rockets may take place over the next couple of years.



March Highlights

EV In A Box—Build this electric car from a kit, or convert your old clunker.

■ **Super Close-Up View**—Scientists power up a microscope that can see single atoms.

■ **3-In-1 Laptop**—New lightweight computer is a quick-change artist and an instant turn-on.

Editor: Jim Wilson
Reporters: Stefano Coledan,
Steve Ditlea, Sandra Erwin,
Mike Fillon, Cliff Gromer,
Scott Oldham, Bob Reichenbach

Technology Watch

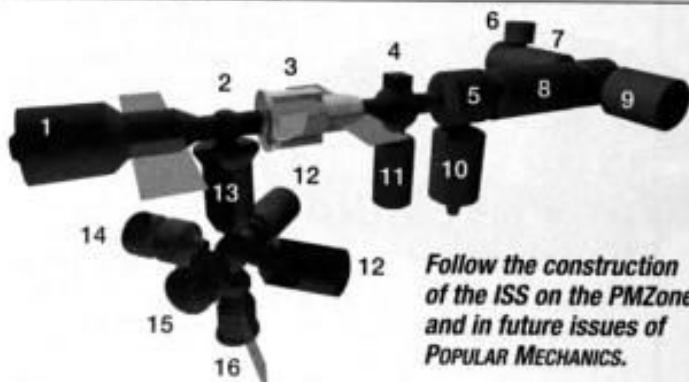


International Space Station Takes Shape

The most complex construction project ever attempted has begun with the joining of the first two elements of the international space station (ISS). Over the next five years, 44 shuttle missions and Russian launches and 1000 hours of space walks will take place as astronauts assemble about 100 elements into a permanent orbiting scientific lab.

The Russian-built *Zarya* (labeled "3" on the diagram below), which is sometimes referred to as a space tug, will provide power and propulsion, and act as a temporary docking port. The first U.S. component in orbit, *Unity* (5), is the connection point for the U.S. laboratory (8) and crew habitat (10).

A truly international effort, the 16-nation, 900,000-pound ISS will include Japanese (6 and 7) and European Space Agency (9) laboratories. Mating adapters (2 and 4)



Follow the construction of the ISS on the PMZone and in future issues of POPULAR MECHANICS.

will attach the Russian service (1) and docking (11, 13 and 15) modules, as well as research (12) and life support modules (14), and provide for Soyuz spacecraft (16) docking.

"None of it's easy, but if it was easy, it wouldn't be worth doing," says Don Pallesen, a spokesman for NASA's Johnson Space Center.

PLUTONIUM

The repository will have two air-circulation systems separated by movable airlocks.

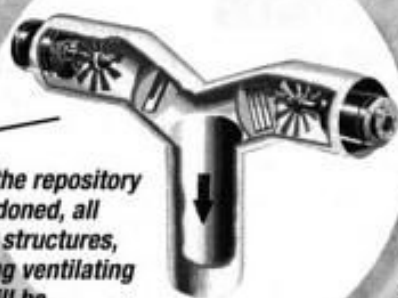
Depending on conditions, the tunnels, or drifts, in which waste casks are placed will be reinforced with precast or cast-in-place concrete linings.

Each disposal container, or cask, will hold 21 or 44 fuel assemblies. Each cask contains enough plutonium to make at least 20 nuclear bombs.

Radiation-shielded trains will move the casks into the drifts. Note the movable airlock, shown open (though it's normally closed), on the right.

Automated inspection machines may be used to monitor for radiation leaking from the casks.

PERIL



A mine not far from Las Vegas is about to become the most radioactive place on Earth.

BY JIM WILSON

► Nuclear waste is hot,

physically and politically. And there is no place where you can feel the heat more than at Yucca Mountain, Nev. The federal government is preparing to make this hauntingly beautiful patch of desert 100 miles northwest of Las Vegas the most radioactive place on Earth. Beginning as early as 2010 a network of tunnels will be dug and simultaneously loaded with the most radioactive waste from the 100 or so nuclear reactors that supply about 20% of the nation's electricity.

ENERGY

Building a massive mine to store nuclear waste wasn't in anyone's original game plan. At the dawn of the nuclear age engineers saw the "spent fuel" that came out of reactors as potentially more valuable than the slightly enriched uranium dioxide "fresh fuel" that went in. Nuclear fission does more than make the steam that spins electric generators. A portion of the uranium fuel undergoes a transformation, yielding a cornucopia of radioactive elements. The most troubling of these is plutonium-239, which can be chemically separated and then used to make fuel for other types of power reactors and nuclear bombs.

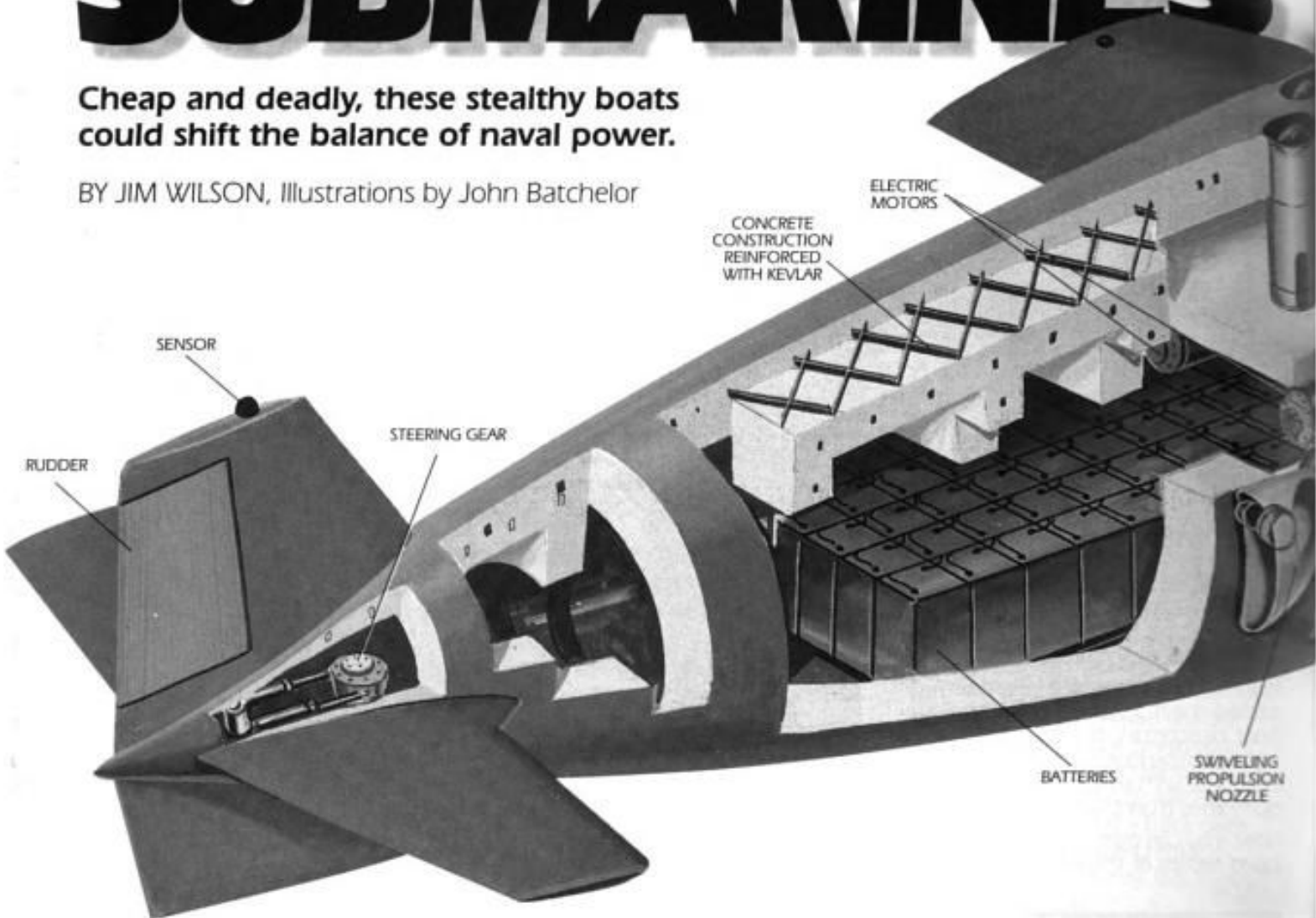
As the concentration of these newly created elements increases in the fuel, the thermal efficiency of the reac-

What the United States views as nuclear waste, some countries consider nuclear fuel. After all the waste casks have been placed, but before the repository is closed, the spent fuel could still be removed and shipped to a reprocessing plant. If the waste stays put, a fence, warning signs and files in government archives would be the only indications of the vast mining operation.

CONCRETE SUBMARINES

Cheap and deadly, these stealthy boats could shift the balance of naval power.

BY JIM WILSON, Illustrations by John Batchelor



Concrete submarines could

be the dumbest idea in naval history. Or, they just might give poor nations a way to checkmate their richer, more technologically savvy foes.

Going to sea in what amounts to a hollow rock is actually a well-proven idea. Concrete ships carried cargo

DEFENSE

during both world wars. College kids hold an annual concrete canoe race. And you'll find concrete barges, houseboats and sailboats in scores of marinas.

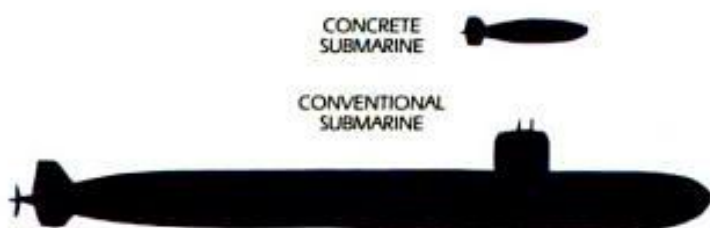
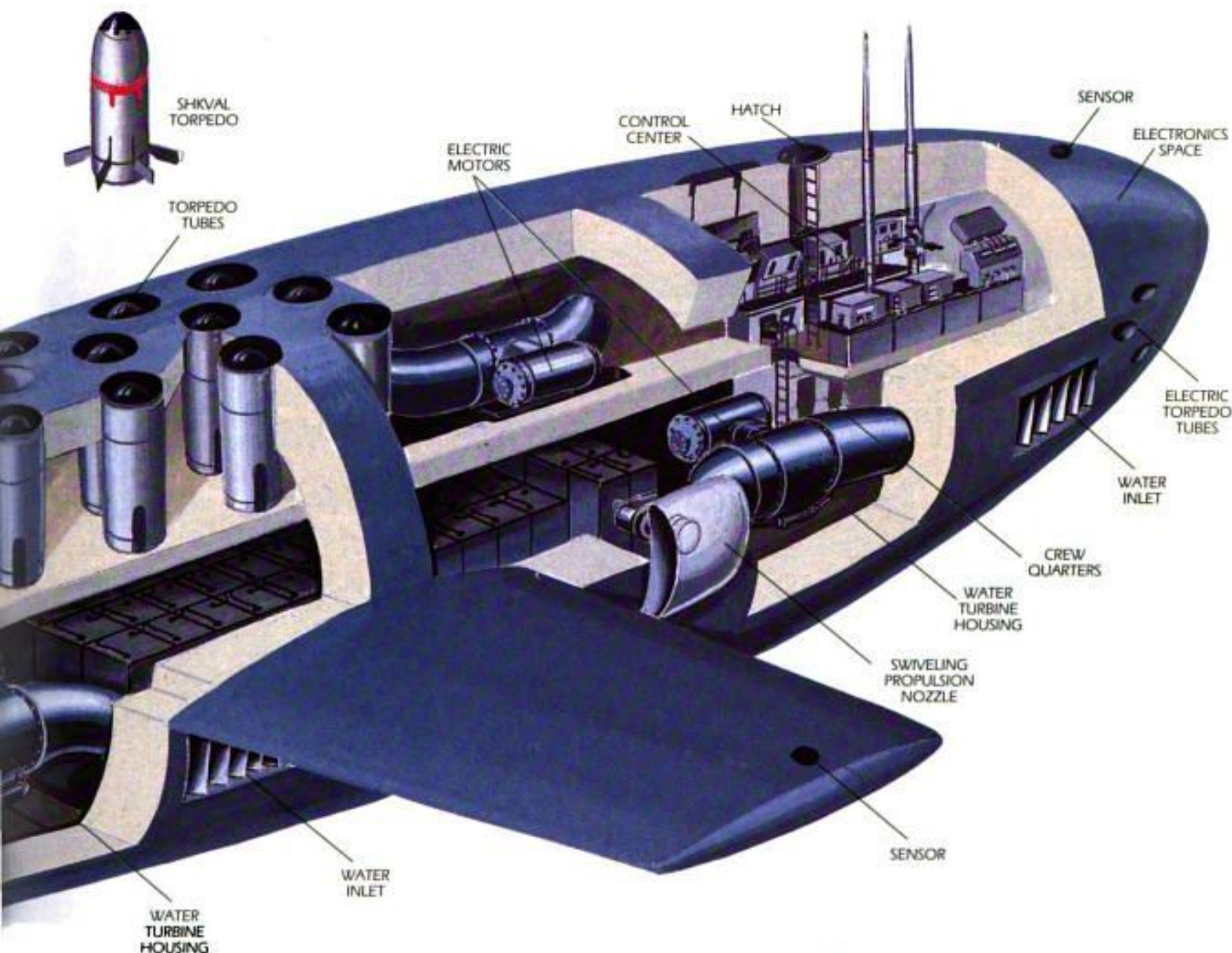
Now the Russians want to take the idea to a new low—with concrete submarines. Called C-subs, these 6-man vessels (shown above) will differ from today's submarines in several important ways. Conventional

submarines float until they take on water. C-subs will stay afloat by using four electric turbine pumps to propel water downward. The swiveling nozzles that direct this flow also will enable the C-sub to move.

C-subs will also fight differently. Conventional submarines prowl the seas. On a typical patrol, a C-sub will sink offshore, waiting for enemy ships to pass overhead. Then it will fire vertical-launch torpedoes. Because concrete is strong in compression, C-subs could sink well below the 1800-ft. "crush depth" for steel, according to the British Ministry of Defense (MOD). And on sonar displays, the concrete will be hard to distinguish from a sandy sea bottom.

MOD knows about C-subs because they resemble an idea floated by German marine engineer Heinz Lipschutz

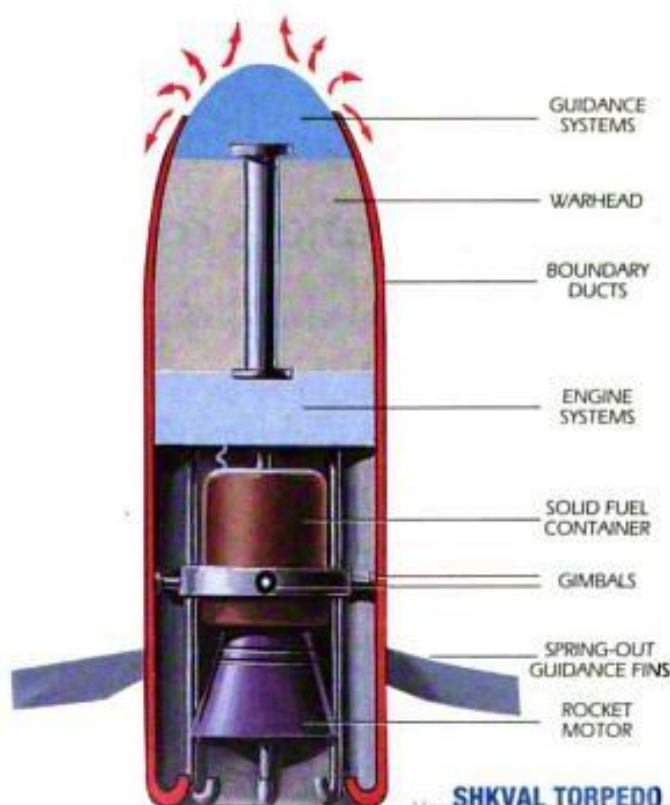
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in 1957. The Royal Navy wasn't interested then, but MOD thinks that the new Russian C-sub has a feature that poor countries will find hard to resist—rocket-powered torpedoes. Developed in the early 1990s and code-named Shkval—Russian for squall—they can travel through the water at 230 mph, about four times as fast as conventional torpedoes.

Shkval-launching C-sub could shift the balance of naval power, cautions British defense analyst Julian Nettlefold: "With these craft being potentially so cheap to make, there is the danger of countries such as Iran and Libya using them to threaten American carrier groups or to barricade certain ocean routes."

A Shkval torpedo reaches high speeds by diverting some rocket thrust through its nose, thus creating a low-friction path.



SHKVAL TORPEDO

Материал подготовлен на основе информации...

Science

21ST CENTURY CARRIER FORCE

Our naval warfare strategies will change the way America's aircraft carriers win victories at sea.

BY JIM WILSON

Illustration by Tom Freeman



The exact shape the Navy's next carrier, CVN-77, should take is a matter of considerable debate within the defense community.

► It is a beautiful night on the

water. The Gulf of Mexico is as calm as a country lake and a wispy sea breeze gently stirs the moist tropical air. Stars bright as flashbulbs speckle the cloudless

COVER STORY

sky. All this tranquillity, though, is probably lost on the pilot of the fast-approaching jet. He is about to experience the most terrifying event of his young life, his first night landing on an aircraft carrier.

From our vantage point, on the landing safety officer's platform of the *USS John C. Stennis*, his plane seems to hang motionless. It is an optical illusion: In fact, 51,000 pounds of F-14 Tomcat are bearing down on us at 154 mph. Less than a heartbeat after we recognize the jet's distinctive twin-fins, its tailhook hits the deck about 50 ft. to our left. It throws off a shower of sparks that follows the plane like it's a grounded Roman candle. The rolling thunder of the jet's afterburners—an insurance policy that guarantees a speedy takeoff if the arresting cable breaks—crashes through the earplugs we're wearing.



would evolve to become the most powerful fighting machines afloat. Today, as the Navy prepares to build its last Nimitz-class carrier, the still-unnamed CVN-77, these awesome floating airports find themselves the target of the next explosive change in naval warfare.

The Last Nimitz

"CVN-77 is our transition carrier," says Rear Adm. David Putnam Sargent Jr., of the Naval Sea Systems Command in Arlington, Va. "Our objective is lowering the ownership costs of Nimitz-class [carriers] and at the same time to allow us to develop new technologies that can be used in the future." The carrier after CVN-77 currently exists as a research and development program, but it could be cast in steel before long. It is known by the code name CVX. The exact form that CVX takes will be shaped by two potentially conflicting forces: the practical lessons the Navy will learn in building CVN-77 and emerging naval strategies that reflect the new political realities of the post-Cold War era.

In 75 years of conducting air operations at sea the Navy has worked most of the bugs out of its carriers. One that persists, which the Navy hopes to avoid in CVN-77, has roused us from a sound sleep onboard the *Stennis*. The noise is so loud the ceiling of this state-room—PM ranks a lieutenant commander's quarters—could be the underside of a demolition site. The next morning the ship's executive officer explains that a crew spent the night servicing a jet-blast deflector located directly overhead.

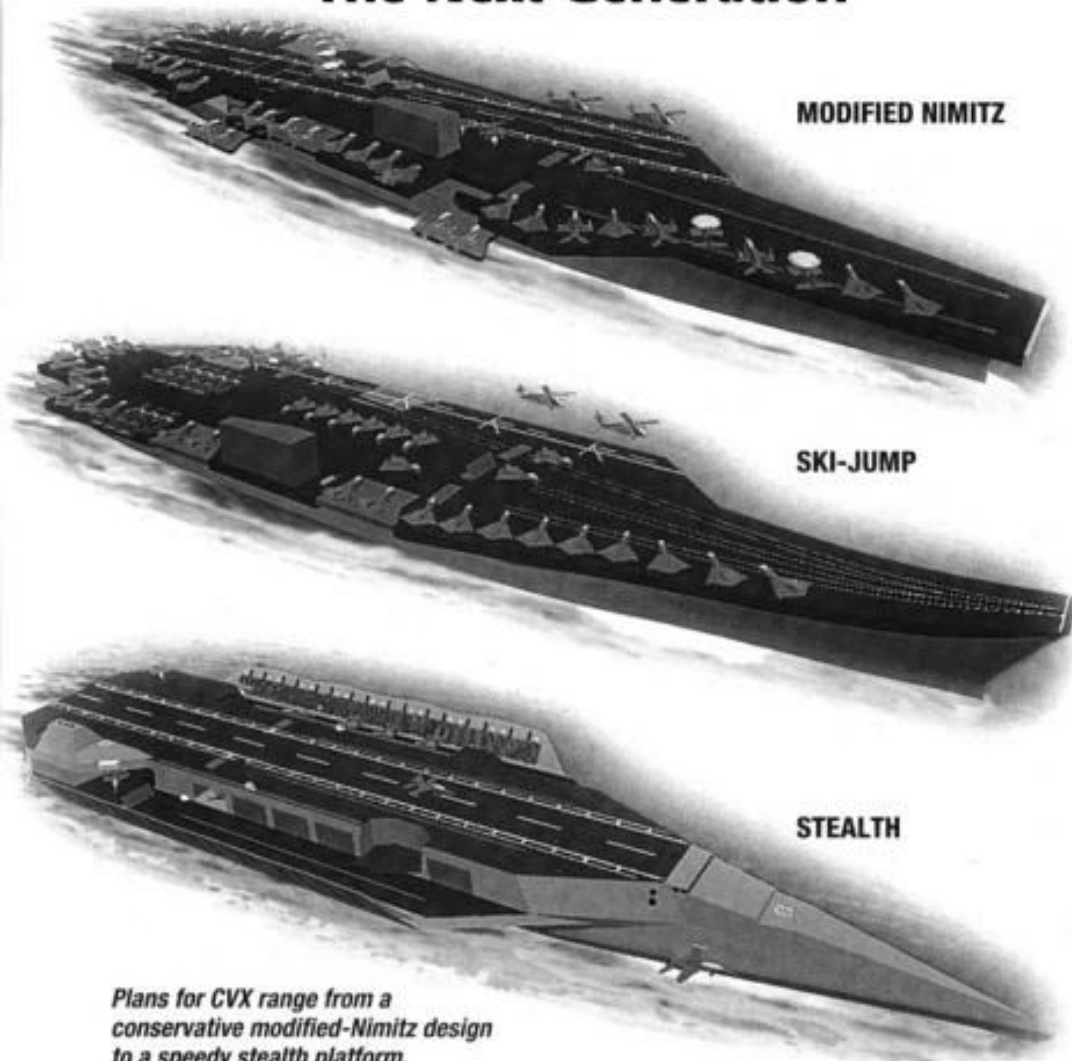
These large steel plates, one behind each of the carrier's four catapults, protect aircraft handlers from 2300° F jet exhaust. The plates are cooled with seawater,

The noise stops abruptly, signaling that the plane has come to a complete stop.

In the distance we can see a band of aircraft handlers rising from the shadows. They quickly inspect the plane and lock it into the nearby catapult. The same pilot spools up the twin engines. A sharp salute signals he is ready for takeoff. Enough high-pressure steam to fling a pickup truck $2\frac{1}{2}$ miles surges through the catapult's power cylinders. The pilot rockets into the night sky—and a new career as a naval aviator.

For more than half a century, the Navy's ability to launch and recover aircraft at sea has been the powerful swift sword of American foreign policy. The *Stennis* CVN-74, on which **POPULAR MECHANICS** has deployed, will carry this tradition forward far into the 21st century. One of eight operational Nimitz-class carriers, she traces her heritage and basic "flattop" design back more than 75 years to when the collier *Jupiter* was topped with a wooden flight deck and rechristened as the Navy's first aircraft carrier, the *Langley* (see "Navy Building Battleship Of New Design," March 1921, page 331). Born in an era when nations projected their wills from the barrels of big guns atop battleships, flattops

The Next Generation



Plans for CVX range from a conservative modified-Nimitz design to a speedy stealth platform.

which is plentiful but also corrosive. "It has been a maintenance headache on all carriers," Richard R. Doerner, design manager at Newport News Shipbuilding's Carrier Innovation Center in Newport News, Va., later tells PM. When CVN-77 puts to sea in 2008, the metal deflectors will probably be replaced with a passive heat shield to eliminate the need for seawater and its attendant maintenance problems.

Smaller Crews

This may seem like a small modification, but the Navy sees such steps as essential to making a 12-carrier fleet affordable. On average, a Nimitz-class carrier costs about \$4 billion to build and \$2 billion a year to operate, according to the General Accounting Office. The 80 or so planes are extra. And the fact that they become obsolete faster than the ships adds substantially to total costs. The F/A-18E/F program to equip carriers with the next generation of aircraft comes with an \$81 billion price tag. Add to this the cost of the scores of ships needed to ser-

vice and protect carrier battle groups and you get a sense of the cost problem. "Some members [of Congress] believe that alternatives to the Nimitz design offer a more cost-effective means of basing aircraft at sea," says defense analyst Scott C. Truver.

Following the lead of industries that have successfully used automation to reduce the size of workforces, the Navy is looking to downsize the 5000-man crews of Nimitz-class ships. Although it hasn't set precise numbers for the size of future crews, one hint of the Navy's long-term goal comes from its enthusiasm about an automated bomb-handling system that will let one sailor do work now handled by nine.

Some changes will be more obvious than others. As a Nimitz-class carrier, CVN-77 will have the same below-deck structure as her sister ships, right down to twin nuclear reactors (see "Show Of Force," March 1990, page 49). Above the flight deck the change that will most visibly set her apart will be the replacement of her island—a multistory structure re-

sembling an airport control tower—with two low, squat control centers.

On flattops the island typically houses the helm and navigation centers, as well as observation suites for the carrier air group commander, captain and, from time to time, the admiral responsible for the battle group. From the observation areas, the views of the flight deck and ocean are spectacular. Unfortunately, the radar return that bounces off these towers makes a carrier stand out like the proverbial sore thumb. Current plans for CVN-77 call for replacing the broad expanses of windows with broad expanses of display screens that will show satellite and combat-radar imagery. The change will make it possible to reduce the single, tall island to two small structures shaped to scatter rather than reflect signals transmitted by enemy radar.

Whatever the eventual crew size and deck configuration of CVN-77, defense analysts believe one thing is almost certain: She is likely to be the last of the large flattops. However, this downsizing isn't the Navy's idea, but the enemy's.

New Enemies

"When the steel for CVX is poured in 2006, the final shape will represent almost 80 years of carrier development," says Capt. Mark O'Hare, the Navy's carrier program manager. The overall shape of the flattop carrier was cast during the Second World War. Changes made to carriers during the Cold War era stemmed mainly from the switch from oil to nuclear fuel and the need to fine-tune weapons systems to keep ahead of the Soviet navy.

After preparing for so long to engage the Soviet Union on the deep blue waters of the open seas, naval aviation planners now find themselves facing a totally unexpected turn of events. "With the Soviet Union's collapse in 1991 there is simply no blue-water enemy to sink," says Andrew F. Krepinevich Jr., of the Center for Strategic and Budgetary Assessments, a Washington, D.C.-based think tank that analyzes defense strategies.

Krepinevich and some other military analysts see this lull in hostili-

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POWER BOAT!

**Inside America's
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Technology Watch

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Termites Teach A Cool Lesson

Termite mounds are true wonders of engineering. While the temperatures of the African terrain outside can range from 35°F at night to 104°F during the day, inside they must be kept at exactly 87°F to allow the insects to “farm” the fungus they need as food. Termites do it by venting breezes in at the base of the mound. The warm air travels through chambers cooled by wet mud that

the termites carry up from water tables below.

Taking a lesson from termites, architects for the Pearce Partnership have applied the same

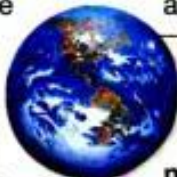
idea to Eastgate, a new office complex for Old Mutual Insurance and Real Estate in Harare, Zimbabwe.

The complex is actually two buildings linked by

bridges across a shady, glass-roofed atrium open to the breezes. At night, fans draw cool, fresh air in from the atrium, and blow it upstairs through hollow spaces under the floors and from there into offices through baseboard vents.

As the air warms during the day, it is drawn out through ceiling vents. This air exits through 48 round brick chimneys on the roof.

Designing with nature has a big cash payoff. The \$36 million complex cost \$3.5 million less than a conventional building because it didn't need an air-conditioning plant, and it costs 10% less to operate.



January Highlights

NASA's New Millennium—Deep Space 1 marks a new era in space exploration.

■ **A Wrenching Flight**—Gyrocopter kit bolts together for fast takeoffs from short runways.

■ **Chip Stumps Shoplifters**—New ID tag can disable products that fall into the wrong hands.

Editor: Jim Wilson
Reporters: Annette Cary, Stefano
Coledan, Sandra Erwin, Mike Fillon,
Jay Levine, Andy Turnbull

Technology Watch

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Inflatable Houses On Mars

A lightweight residence for astronauts on Mars missions is taking shape in a cavernous hangar at NASA's Johnson Space Center (JSC) in Houston.

Called TransHab, the 37-ft.-tall, 25-ft.-dia. module would fold up for launch and later inflate like a balloon. It would give astronauts the unprecedented luxury of a private bedroom as they make the 6-month cruise to the red planet. Similar 12-ton

modules sent earlier and inflated on the Martian surface would provide a temporary home (above).

TransHab would be made of alternating layers of ceramic fiber

webbing and polyurethane foam, with reflective Mylar on the outside and bullet-stopping Kevlar on the inside. This 1-ft.-thick high-tech sandwich would protect the crew from

micrometeorites better than metal, says Horacio de la Fuente, JSC's TransHab deputy manager.

Gaps in the foam layers would allow the shell to bend and shrink to fit inside the space shuttle's cargo bay, or inside the shroud of some yet-to-be-designed Mars rocket. Once in space, air would inflate the bladders to stiffen the outer shell.

Although NASA is years away from committing to a manned Mars mission, it is considering TransHab for use in Earth orbit. A decision on whether to fund the project as part of the International Space Station could come this fall.



September Highlights

Get Tough With Diamonds—New coating process will produce superhard tools.

■ **Entertaining Little Idea**—Trillions of molecule-size emitters to create realistic 3D TV.

■ **Plastic Tanks**—Steel looks strong, but polymers offer lighter combat protection.

Editor: Jim Wilson
Reporters: Stefano Coledan, Mike Filon, Cliff Gromer, Leslie Hicks, Barry Rosenberg, Bill Spence

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Technology Watch

Aviation • Computers • Energy
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Recycling F-16s For Unmanned Combat



With the F-22 air-superiority fighter and Joint Strike Fighter tactical aircraft scheduled to become the A-Team of America's war-fighting capability after the year 2000, what is to become of humble 20th-century technology?

Lockheed Martin and Tracor Flight Systems

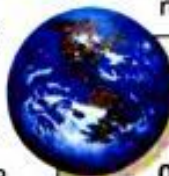
want to adapt F-16 technology for use in unmanned combat

aerial vehicles (UCAVs) and command planes.

Both types of craft would

use powerplants and landing gear developed for the F-16. Only the command plane would have a complete suite of avionics, mission planning and fire-control systems. UCAVs would simply follow instructions.

Eliminating pilot life support and safety systems would enable UCAVs to carry more weaponry, making a robot-controlled squadron a more potent fighting unit than a crewed assault force.



July Highlights

Rethinking Radon—The cancer risk of a common gas may be overestimated.

■ **Fishy Swimmer**—Flipping fins push an underwater vehicle better than a propeller.

■ **Tiny Fireboat**—This rigid-hull inflatable can really run circles around the big guys.

Editor: Jim Wilson
Reporters: Louis Brill, Stefano Coledan, Brad Dunn, Jim Dunne, Mike Fillon, Kathleen Gleaves, Scott Gourley, Cliff Gromer, Ken Juran, Bill Rhodes, Barry Rosenberg

CITY AT SEA

Nearly a mile long and 25 stories high, *Freedom* will be the largest vessel to ever sail the seven seas.

BY JIM WILSON, Science/Technology Editor
PM Illustrations by John Batchelor

• Norman L. Nixon loves to talk about the enormity of it all. "Walk in a straight line for about 12 minutes," he says. "If you don't dawdle, you'll cover slightly less than a mile. Now, make a right turn and walk beyond the length of two football fields. Duplicate these lines to make a rectangle, then look up to the height of a 25-story building. This is what *Freedom* will be." Listening to him talk about it, you begin to understand why Nixon doesn't refer to *Freedom Ship* as the world's largest vessel, but the

Freedom will dwarf the *Queen Elizabeth II* and become a permanent home for 50,000 people.

span a distance 15 times its height. "A ship with an effective depth of 80 ft. of hull [measured from keel to main deck] can theoretically span a maximum of 1200 ft.," Nixon says. "On *Freedom*, the effective beam runs 350 ft., from the bottom of the ship to the aircraft runway." The result is a 4320-ft.-long floating beam that draws 37 ft. of water as it rides atop waves, rather than plowing through them.

"We're not doing anything new," Nixon says. "We've taken technologies used in one area and applied them here." Indeed, Nixon says that during World War II the Navy used floating docks longer than *Freedom*. More recently, Kvaerner, the Norwegian ship and oil platform builder, proposed that the U.S. Department of Defense build a 5249-ft. floating airfield capable of supporting 10,000 troops. Called *SeaBase*, it would use Kvaerner's patented linking system to join three giant semi-submersible drilling rigs into a landing field.

Although similar in scope to these massive seagoing projects, *Freedom* actually began as

an equally ambitious project on land. "We were on the verge of building an entirely new city on the 50-sq.-mile uninhabited island of East Caicos, south of the Bahamas. It was to serve as a modern Hong Kong," says Nixon. "Had the then chief minister not lost his reelection bid, we would probably be at work on the island today. In retrospect, the loss of this opportunity appears to have been the best thing that could have happened."

When a search of natural and manmade islands failed to turn up a suitable alternate location to East Caicos, one of *Freedom* city's original backers suggested building an island that could visit different countries each month. Strange as this suggestion seemed, it was something Nixon had actually done before. During

the 1980s, he was part of a team of engineers who built a \$1 billion modular ethylene plant in Japan and then towed it as more than 100 modules to Saudi Arabia, where it was reassembled. Encouraged by Nixon's hands-on experience in seagoing modular construction and the fact that he has licenses to practice structural, electrical, sanitary and civil engineering, his early supporters elected to follow his dream to sea. "And so," he says, "the *Freedom Ship* project was born."

Freedom promises to be as different from today's oceangoing vessels as the *Queen Elizabeth II* is from the *Mayflower*. Starting with the keel, *Freedom* doesn't have one. This backbone is missing because *Freedom* is constructed of 520 airtight steel cells.



Each will measure 80 ft. tall. Depending upon its location, each will be 50 to 100 ft. wide and 50 to 120 ft. long. Assembled ashore on rails, they will be bolted together to form base units, each about 300 by 400 ft. These will then be floated out to sea and joined to form the completed base.

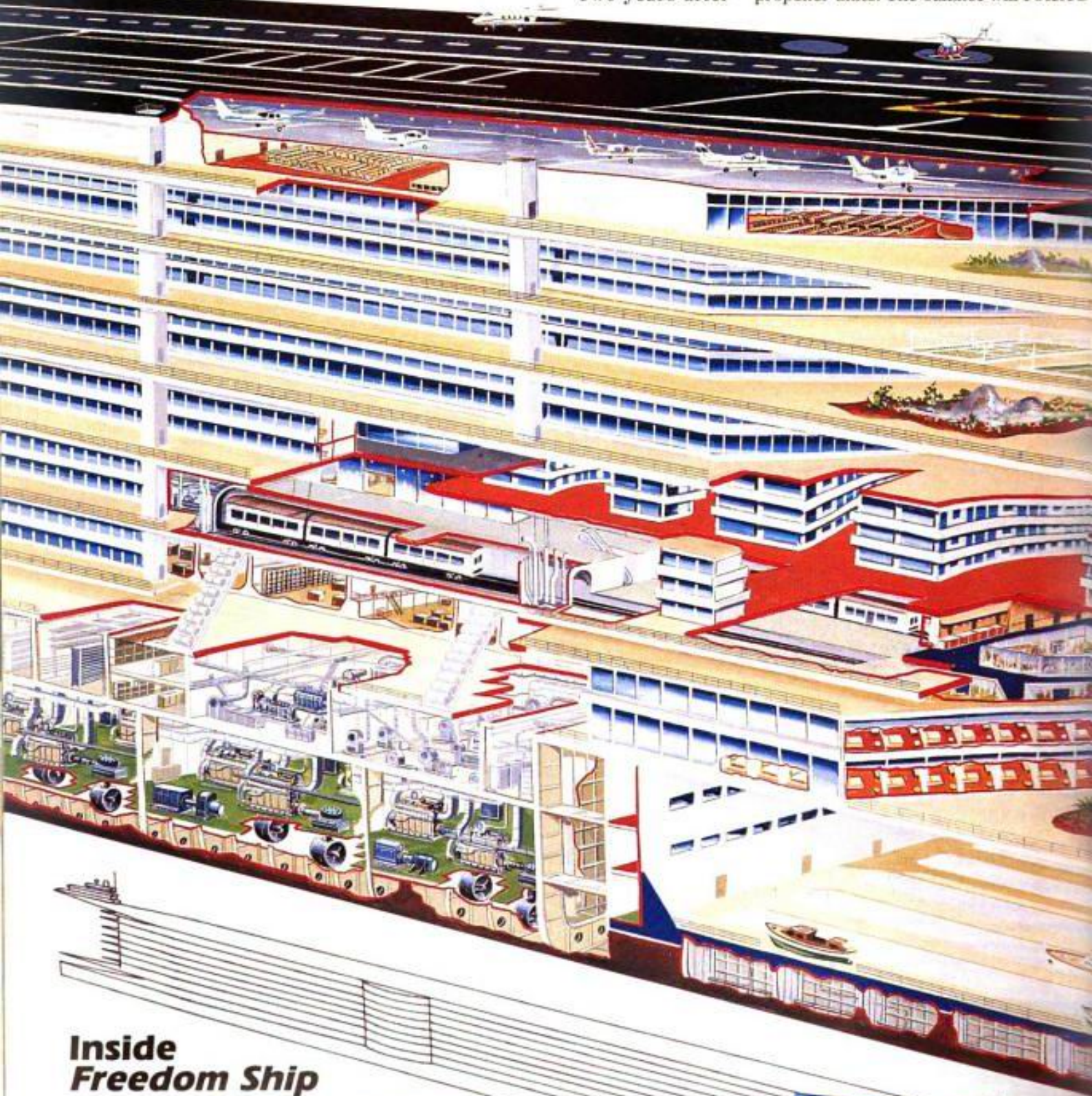
About 10 months after the start of construction on the first air-

tight cell, three base units will have been assembled at sea. At this point, the tempo of construction will increase. Meanwhile, on shore, four assembly lines will be dedicated to building airtight cells. At sea, work will begin on the 25-story superstructure. By the 17-month mark, the last base unit will be bolted in place and the 25th level completed.

Two years after

the start of construction, 4000 of *Freedom's* planned 21,000 units will be ready for occupancy. Her boilers will be fired up and she will set sail.

Well, not exactly. *Freedom* won't have the sort of boilers you find on traditional ships. She will be propelled by 3700-hp motorized units protruding through 100 of her watertight cells. About half of these will be shrouded propeller units. The balance will rotate



Inside Freedom Ship

Two of the most striking differences between *Freedom* and existing cruise ships are its jet-capable landing strips and the marina. The cutaway of the highlighted area (above) shows that the interior will be designed more like an urban area, with open spaces and transportation links, than a traditional ship. The view of the marina promises to be especially spectacular during heavy storms. Because *Freedom* will ride on top of the waves, residents will be able to look down at the troughs dozens of feet below.

AREA
ENLARGED
ABOVE

360°, like those used on tugboats. At about \$1 million each, these are among the world's most expensive marine powerplants. But, again, thinking like an engineer first and architect second, Nixon sees their cost as a bargain. This is because they can be linked to a central PC-type computer system. The helm thus becomes a joystick. And even this isn't necessary. Using GPS, *Freedom's* captain could simply sketch the ship's route on a touch-screen and the \$6 billion ship would find its own way. Theoretically.

park and recreation areas. Nixon has calculated that the resident population can support its own local economy, which means that residents will, in many cases, also be operating businesses at sea, in malls throughout the length of the ship.

As with a land-based city, these amenities and businesses will not appear overnight. The construction schedule calls for *Freedom* to set sail on its first 2-

to furnish blueprints of the completed ship. "Ships are designed by naval architects who then turn them over to structural engineers. We began with the structural engineering and will let the architects make it pretty," he says. In retrospect, this turned out to be a good strategy.

"We originally estimated the average condo sales price would be \$250,000. But it is averaging over \$800,000 per unit," Nixon says. To slow the sale of the most expensive units—those facing the ocean—Nixon recently jacked up the price by 20%.

But, he says, they are still out-selling the less expensive interior units, which cost as little as \$24,000, by 10 to 1. Nixon has responded by adding another level. He also has added a second airstrip atop the ship and increased its capacity to handle 100,000-pound jets.

The "we" to which Nixon repeatedly refers as he describes *Freedom* is a team of 24 engineers and consultants who work with his Sarasota-based firm, Engineering Solutions, via Internet connections.

Like Nixon, many are technical experts from outside naval architecture. Their backgrounds have spurred on a number of decidedly non-nautical solutions to the problems of living at sea. For example, rather than burning the cheapest marine fuel, Nixon has specified engines that require more expensive diesel fuel. His rationale is that this cleaner-burning fuel will reduce long-term engine maintenance costs and create less pollution.

Freedom's proposed environmental systems are also a major break with tradition. For instance, sewage won't be flushed into the ocean. Instead, sanitary waste will be incinerated in electric toilets. "This eliminates the need for wastewater treatment," says Nixon. It is also the reason for a no-pets policy for residents and visitors. Graywater from washing will be recycled into drinking water. Recycling is cheaper than desalinating seawater. Waste heat from the engines will be recycled for spinning generators and heating space and hot water. Nixon even has a plan to turn trash into cash. *Freedom* is so large that it will be possible to store recyclable materials until the ship reaches a port where the scrap will fetch the highest price.

As this issue of PM went to press, Nixon said he was evaluating bids from shipyards in South Africa, Brazil, Poland and Mexico in preparation for beginning construction this year. If the project develops as planned, we'll be filing our next progress report on it from sea. **PM**



Once under way, life aboard *Freedom* will be more like living in a bustling city than being on a vacation cruise. Because of its size, the ship will have its own railway system. Courtyards set about its decks will create interior

year cruise as soon as its first 4000 units are finished.

The rest of the ship will be built at sea. This is strictly an economic decision. "*Freedom* will attract labor from around the world," says Nixon. "The cost of the ship's labor force will be quite low by developed nations' standards."

By now, Nixon has grown accustomed to criticism from the mainstream shipbuilding community. One of its first complaints was his inability

TECH UPDATE

News Of Tomorrow's Technology Today



ANGEL TECHNOLOGIES CORP. ILLUSTRATION AND PHOTO

Airborne Modem Link

ST. LOUIS—A new type of high-altitude aircraft promises to dramatically reduce the cost of reaching out and touching someone with a high-speed modem.

Several projects that use balloons and ultra-efficient aircraft to carry high-speed telecommunications gear are now in development. POPULAR MECHANICS recently dropped in for a look at the project that is furthest along, the HALO—high-altitude long-operation—program created by Angel Technologies.

HALO will fly aboard Proteus, a 79-ft.-wingspan canard aircraft (above and inset) built by Scaled Composites, of Mojave, California. Powered by twin Williams/Rolls-Royce FJ-44-2 turbofan engines, the all-composite Proteus is designed to loiter at altitudes of 52,000 to 65,000 ft. for more than 15 hours at a stretch.

Each Proteus aircraft used for the HALO program will be equipped with a 20-ft.-dia. saucer-shaped pod. Its \$110 million electronics package will work like those aboard



Three HALOs will provide 24-hour service to each major city.

telecommunications satellites.

Currently, the fastest commercial data links—available through satellite or cable connections—operate at 10 megabits per

second (Mbps), and cost as much as \$1000 per month. Angel says it plans to offer HALO users the same speed for about \$250, and a 1.5Mbps connection for only \$40 per month. The first test flight of the Proteus aircraft is scheduled for later this year. Angel expects to offer HALO service in major cities beginning in 2000.

Highlights This Month

- **Slimming Bugs To Death**—"Diet pill" eradicates mosquitoes.
- **Pocket Translator**—Pen reads, translates foreign text.
- **Tiny Transmission**—Powertrain puts muscle on a chip.
- **Soft Landing**—Inflatable legs replace chutes, retrorockets.
- **Heart Saver**—Pump for patients awaiting transplants.
- **Cops Get Second Sight**—Glasses see invisible evidence.

Editor/Writer: Jim Wilson
Reporters: Stefano Coledan, Chris Dean,
Brad Dunn, Mike Fillon, Barry Rosenberg,
Jim Sugar

TECH UPDATE

News Of Tomorrow's Technology Today

Standardized Nuclear Reactors

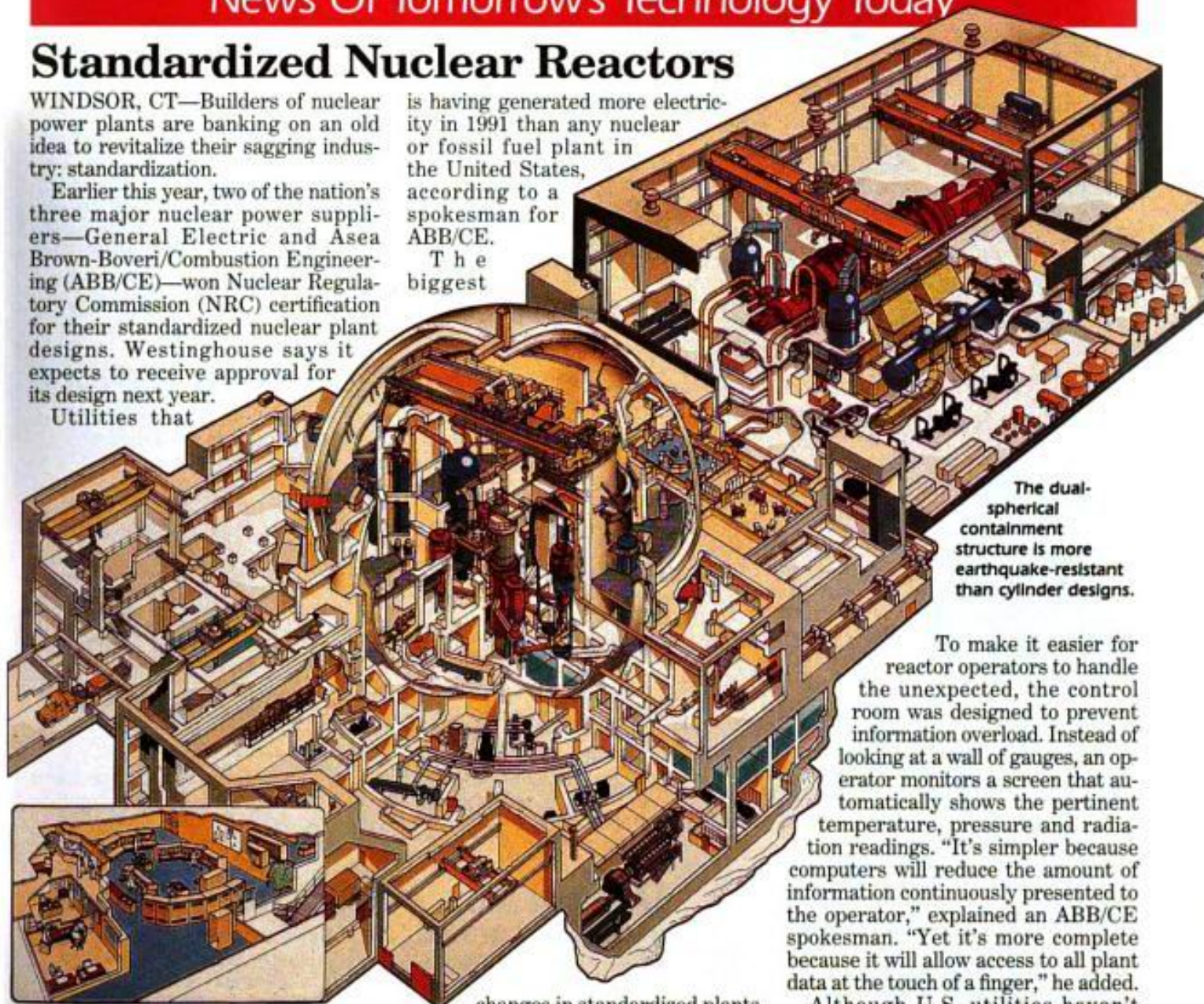
WINDSOR, CT—Builders of nuclear power plants are banking on an old idea to revitalize their sagging industry: standardization.

Earlier this year, two of the nation's three major nuclear power suppliers—General Electric and Asea Brown-Boveri/Combustion Engineering (ABB/CE)—won Nuclear Regulatory Commission (NRC) certification for their standardized nuclear plant designs. Westinghouse says it expects to receive approval for its design next year.

Utilities that

is having generated more electricity in 1991 than any nuclear or fossil fuel plant in the United States, according to a spokesman for ABB/CE.

The biggest



The dual-spherical containment structure is more earthquake-resistant than cylinder designs.

To make it easier for reactor operators to handle the unexpected, the control room was designed to prevent information overload. Instead of looking at a wall of gauges, an operator monitors a screen that automatically shows the pertinent temperature, pressure and radiation readings. "It's simpler because computers will reduce the amount of information continuously presented to the operator," explained an ABB/CE spokesman. "Yet it's more complete because it will allow access to all plant data at the touch of a finger," he added.

Although U.S. utilities haven't ordered a nuclear plant in nearly 20 years, industry insiders believe the pendulum will swing back in their direction. One projection says that by the year 2010 the country will need 21% more electricity.

buy these standardized plants will only have to obtain one NRC license, instead of two as in the past. This change is expected to reduce to four years from as many as 12 years the time it takes to bring a new plant online.

The standard design furthest along in development is ABB/CE's System 80+. The new 1350-megawatt electric plant is based on a pressurized-water-reactor design currently in use at the Palo Verde generating station, near Phoenix. Since the first of this plant's three units went online in 1986, Palo Verde has consistently set power-generation records. Among its distinctions

changes in standardized plants focus on safety features. In the ABB/CE design, the reactor vessel is contained within a spherical "nuclear island," with safety systems located directly below, and protected behind, 3-ft.-thick concrete walls.

Highlights This Month

- **Super Sky Watcher**—New telescope watches satellites.
- **Fast Stroke Spotter**—Tool offers 5-second diagnosis.
- **Solar Wind Tracker**—Orbiting lab samples star stuff.
- **Sharp-Turning Lifter**—Cone wheels offer a new spin.
- **Exotic Fliers**—Experimental aircraft at Oshkosh 97.
- **Long-Term Storage**—Milestone for nuclear waste plant.
- **Earthquake Protection**—World's largest bearing tester.

Editor/Writer: Jim Wilson
Reporters: Leslie Hicks, Barry Rosenberg,
Richard Schrader, Andy Turnbull

AUTOMOBILES

VOLVO SAFETY

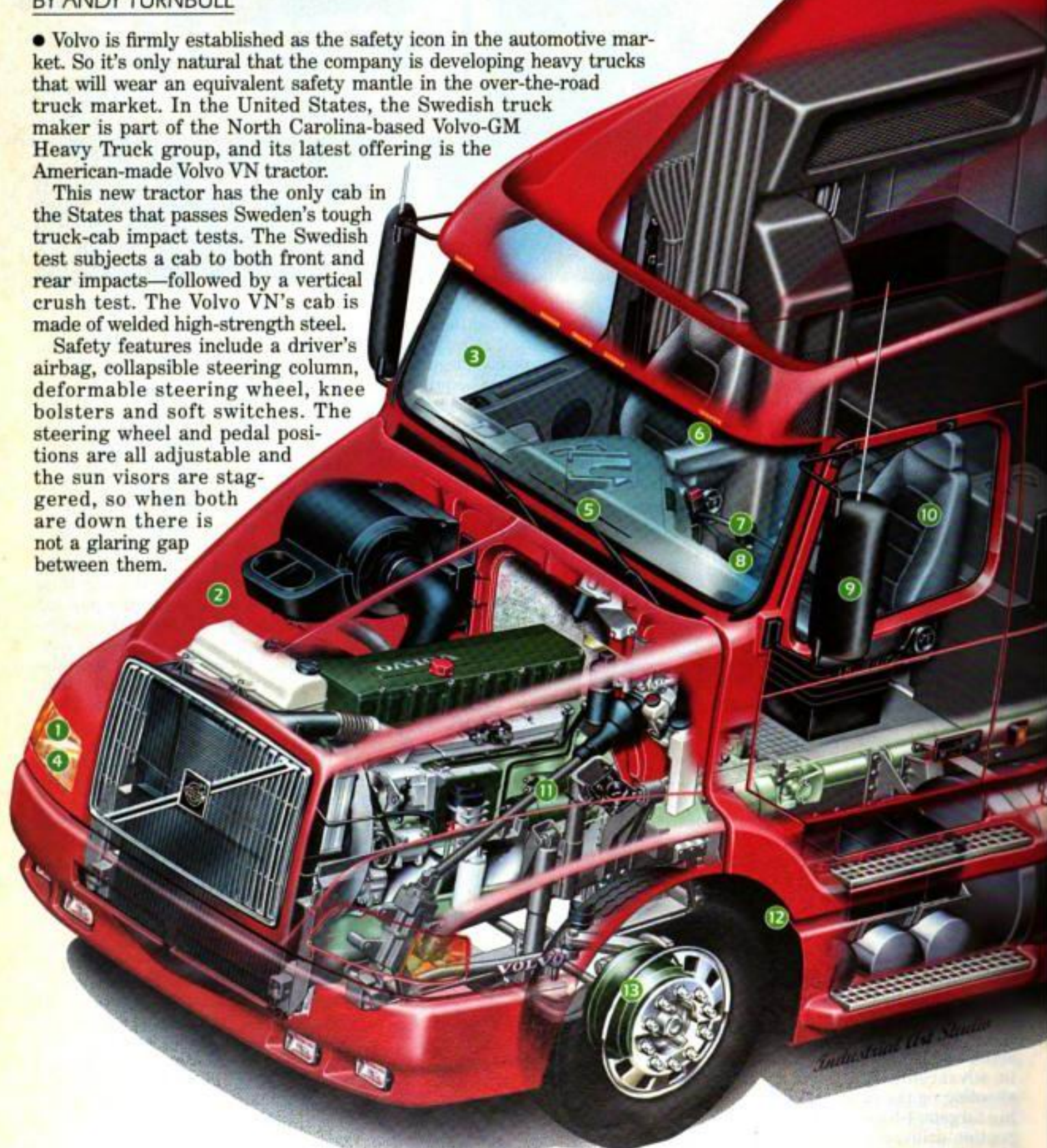
Automotive safety technology in a heavy-duty tractor.

BY ANDY TURNBULL

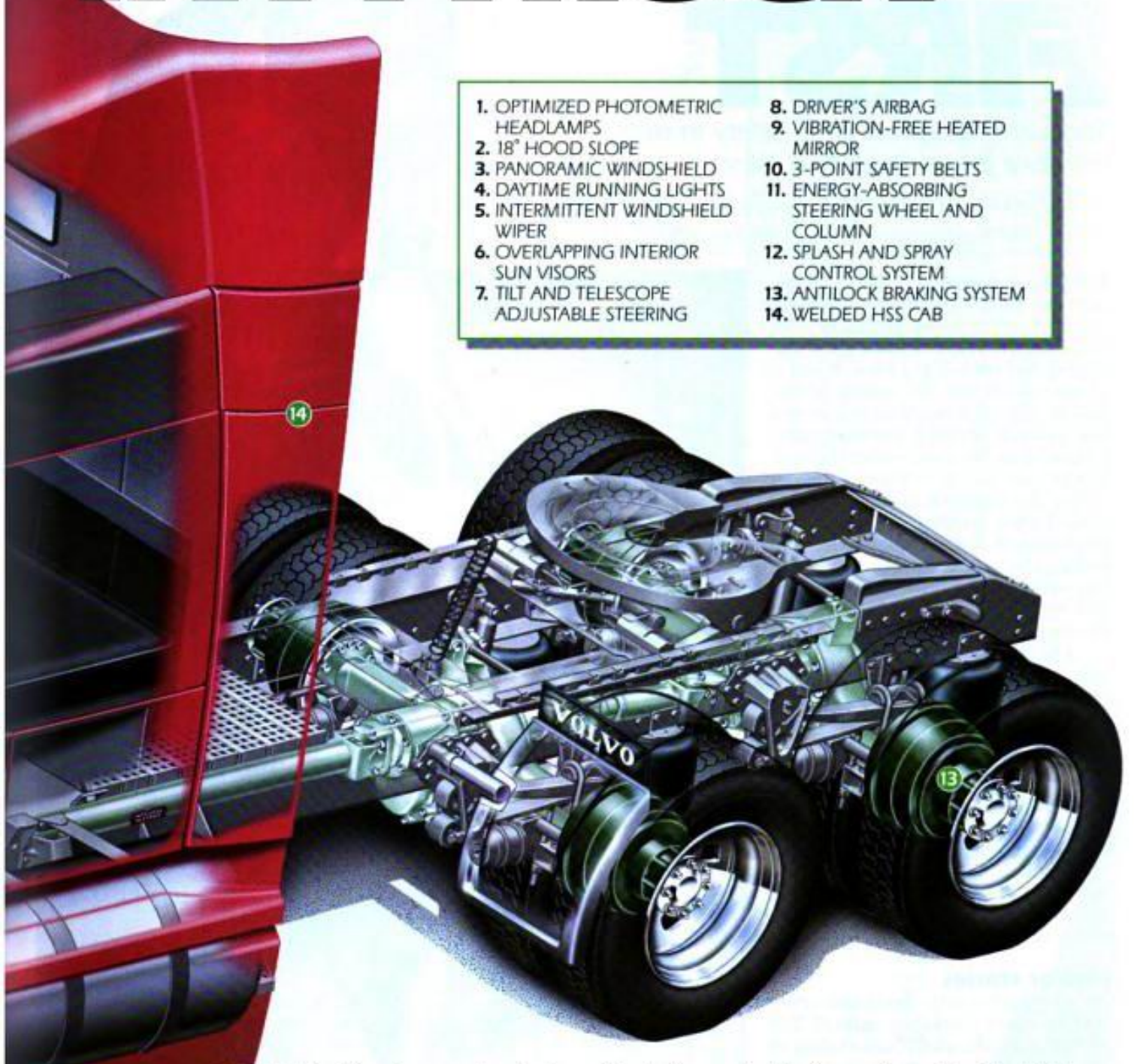
● Volvo is firmly established as the safety icon in the automotive market. So it's only natural that the company is developing heavy trucks that will wear an equivalent safety mantle in the over-the-road truck market. In the United States, the Swedish truck maker is part of the North Carolina-based Volvo-GM Heavy Truck group, and its latest offering is the American-made Volvo VN tractor.

This new tractor has the only cab in the States that passes Sweden's tough truck-cab impact tests. The Swedish test subjects a cab to both front and rear impacts—followed by a vertical crush test. The Volvo VN's cab is made of welded high-strength steel.

Safety features include a driver's airbag, collapsible steering column, deformable steering wheel, knee bolsters and soft switches. The steering wheel and pedal positions are all adjustable and the sun visors are staggered, so when both are down there is not a glaring gap between them.



IN A TRUCK

- 
1. OPTIMIZED PHOTOMETRIC HEADLAMPS
 2. 18° HOOD SLOPE
 3. PANORAMIC WINDSHIELD
 4. DAYTIME RUNNING LIGHTS
 5. INTERMITTENT WINDSHIELD WIPER
 6. OVERLAPPING INTERIOR SUN VISORS
 7. TILT AND TELESCOPE ADJUSTABLE STEERING
 8. DRIVER'S AIRBAG
 9. VIBRATION-FREE HEATED MIRROR
 10. 3-POINT SAFETY BELTS
 11. ENERGY-ABSORBING STEERING WHEEL AND COLUMN
 12. SPLASH AND SPRAY CONTROL SYSTEM
 13. ANTILOCK BRAKING SYSTEM
 14. WELDED HSS CAB

Antilock brakes are standard. And there is further evidence that Volvo's designers set out to create a safe-to-drive tractor. For instance, the tractor's frame is flared 9 in. at the front to allow the engine to be installed very low in the frame. This in turn permitted the designers to create a hood with an 18° downward slope so that the average driver can see the tarmac just a little over 12 ft. ahead of his bumper. That's 4 ft. closer than in previous models. Also, the new cab shape is 14% more aerodynamic than before.

The VN has double rubber seals on the doors, 1 in.

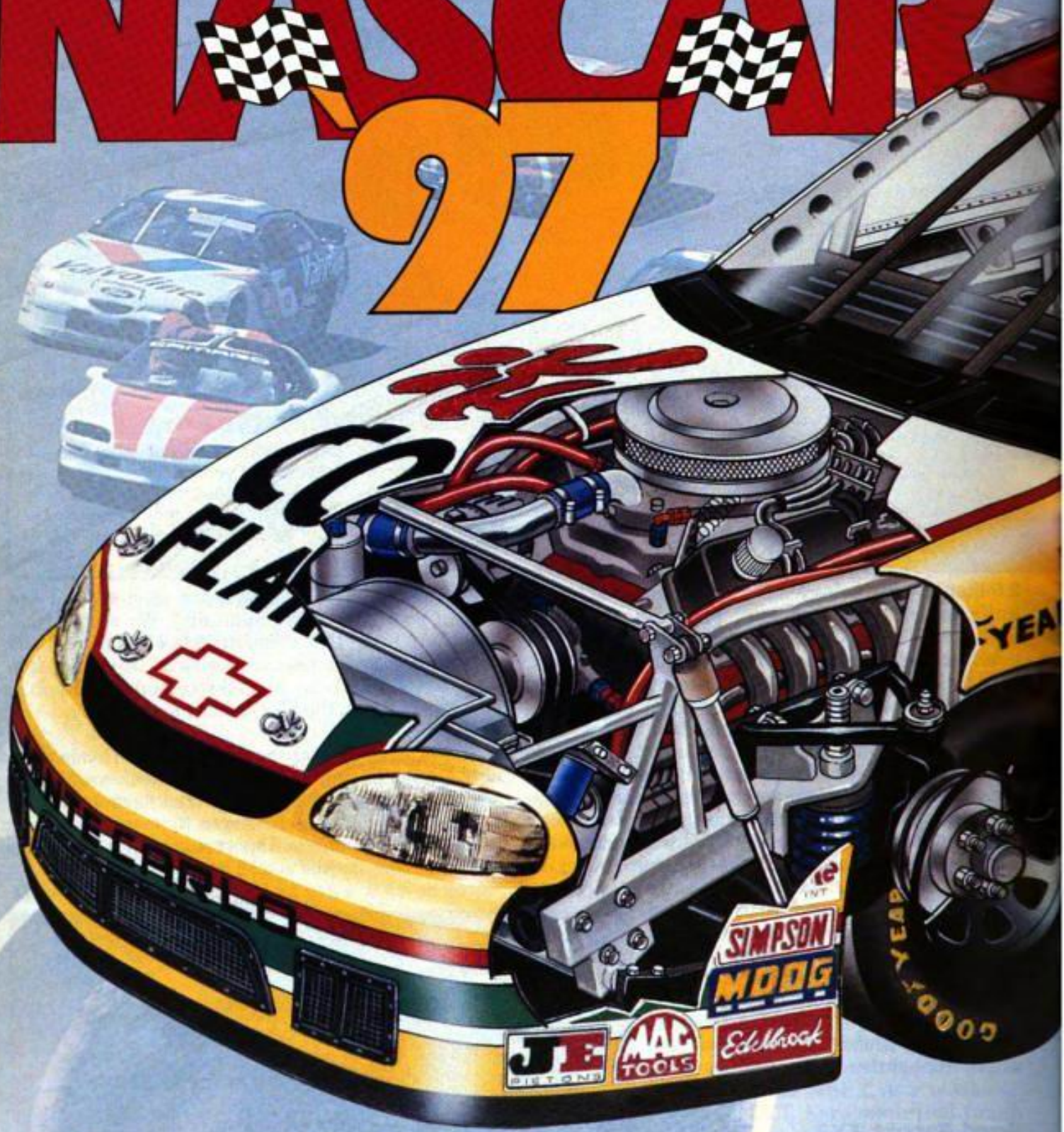
of insulation under the floor and a rubber boot that encloses the whole shift lever and makes the new truck quieter than previous models. Naturally, the cab is isolated from the chassis by an air suspension with four hydraulic dampers. The new tractor comes in long or short wheelbases, single or tandem rear axles, and with integral sleepers.

Like other American big trucks, the VN comes with a choice of Caterpillar, Cummins or Detroit Diesel engines with Eaton or Rockwell transmissions, clutches and axles, and an assortment of suspensions. Unlike other American trucks, the VN offers Swedish-made engines, clutches, transmissions and other components. **FM**

MOTORSPORTS

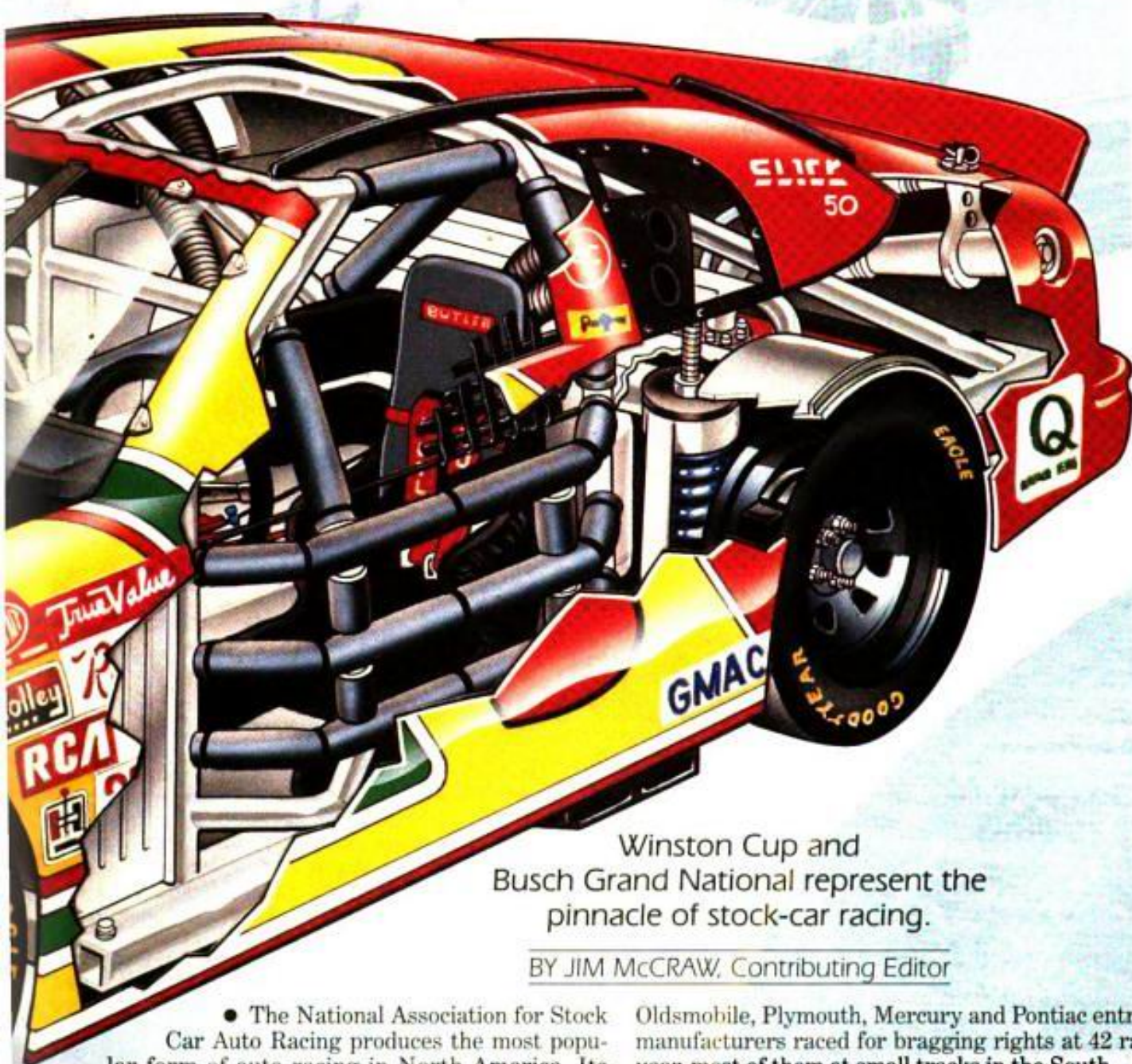
NASCAR

27



Last year, Terry Labonte won the Winston Cup Championship driving Rick Hendrick's No. 5 Kellogg's Monte Carlo. This year's cup is still to be decided by races like the Brickyard 400.

Illustration by [illegible]



Winston Cup and
Busch Grand National represent the
pinnacle of stock-car racing.

BY JIM McCRAW, Contributing Editor

● The National Association for Stock Car Auto Racing produces the most popular form of auto racing in North America. Its Winston Cup and Busch Grand National series are for stock-bodied, Detroit-built cars.

Winston Cup racing is featured on no fewer than eight radio and television networks, and is seen and heard by more fans than any other type of auto racing in North America. The series, brainchild of NASCAR founder William H.G. France, is also the closest and most competitive form of racing we have. Six-hundred-mile races are often decided by less than a car length.

In the old days, the cars really were nearly stock, with steel bodies, elementary rollcages, stock dashboards, gutted interiors, modified stock suspension systems and very small sponsorships mostly provided by car dealers. The NASCAR fields were peppered with AMC, Buick, Chevrolet, Dodge, Ford, Hudson,

Oldsmobile, Plymouth, Mercury and Pontiac entries as manufacturers raced for bragging rights at 42 races a year, most of them at small tracks in the South.

Well, it's all changed now.

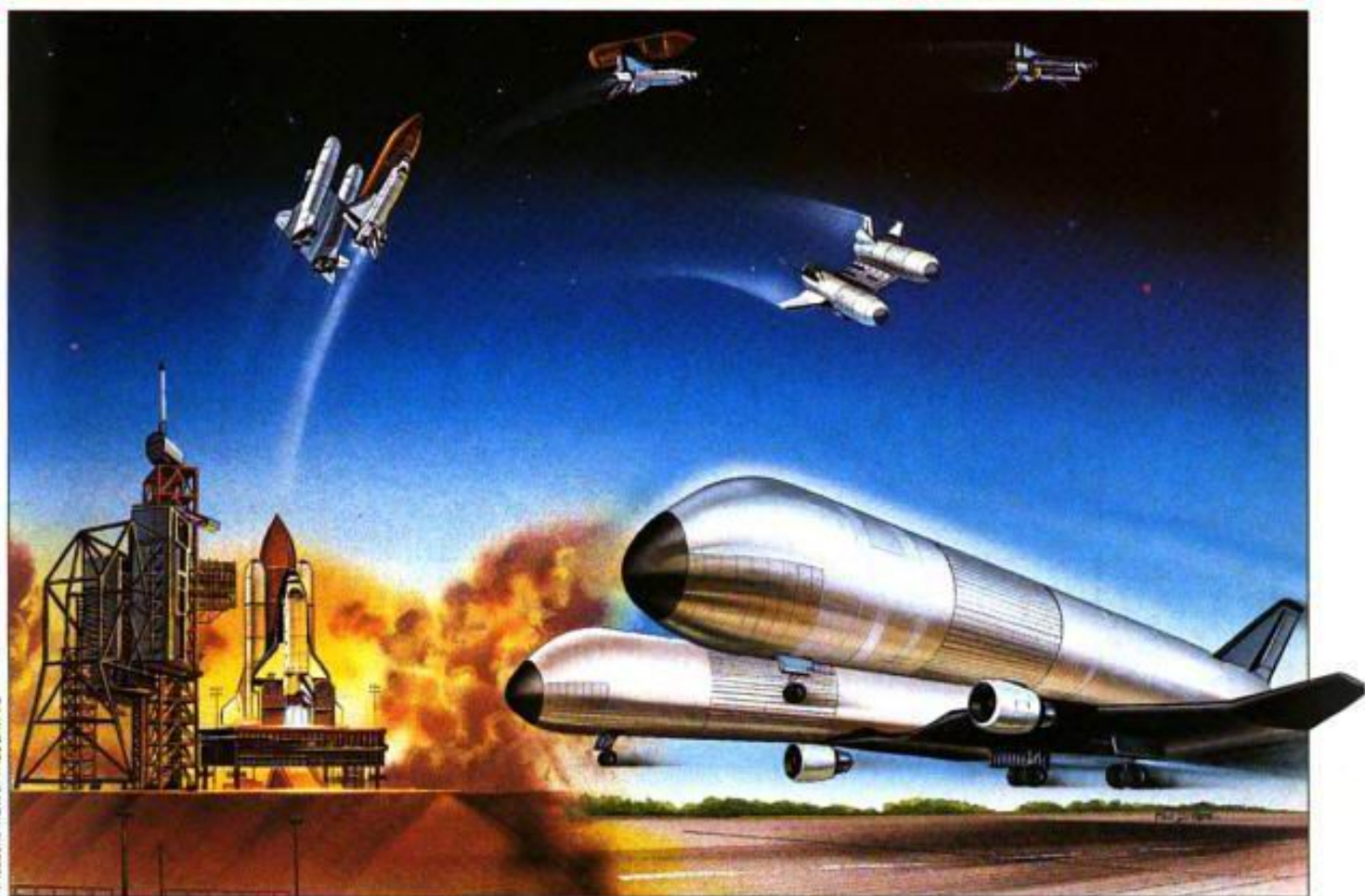
The series

The modern NASCAR Winston Cup series still runs about twice as many races as CART, with 35 events scheduled for the 1997 season. NASCAR is unusual in that its premier race, the Daytona 500, starts the season in early February, unlike the Grand Prix of Monaco and the Indianapolis 500, which are run at midseason.

From the Daytona opener, the Winston Cup series stretches as far away as New England, as well as the traditional Southern stops. The series runs on everything but city streets, from 500 laps around the 1/2-mile Bristol ring to the fastest track of them all, the 2.66-mile Talladega Superspeedway, from 1-, 1½-, 2- and

TECH UPDATE

News Of Tomorrow's Technology Today



PAUL DAWKINS

NASA Mulls Fly-Back Boosters For Space Shuttle

CAPE CANAVERAL, FL—Space shuttle launches someday may provide more than the usual fiery display. NASA is studying the feasibility of using strap-on boosters that land like airplanes, rather than parachute into the Atlantic Ocean as they do now.

What's more, the fly-back boosters would burn kerosene and liquid oxygen during a launch, instead of the solid fuel used in the current design. Liquid-fueled boosters would add an extra margin of safety by making it possible for astronauts to abort during the first 2 minutes of flight. That is impossible with the solid-fuel boosters, which burn until exhausted.

"The program is in a very early stage," said Jerry Smelser, study manager for NASA. "It's very preliminary." NASA awarded contracts to Boeing Co. and Lockheed Martin

Corp. for \$1 million each to conduct the study. Feasibility and cost estimates will be presented by next May, Smelser said.

As in the case of the current reusable boosters, the liquid-fuel rockets would provide most of the thrust the shuttle needs at liftoff. Once their fuel was expended, they would separate from the shuttle, coast for about 9 minutes and land at the Kennedy Space Center. The new boosters would fly back with the help

Several types of liquid-fuel engines are being considered, including Boeing's F-1, which was used in the Saturn moon rockets.

of jet engines, Smelser said. Whether the unpowered craft will have fixed or deployable wings or land attached or separately has not yet been determined. "The return flight is quite open right now," Smelser said.

It's possible that the shuttle's liquid-fuel boosters will be flight-tested by 2002, said Kennedy Space Center director Roy Bridges.

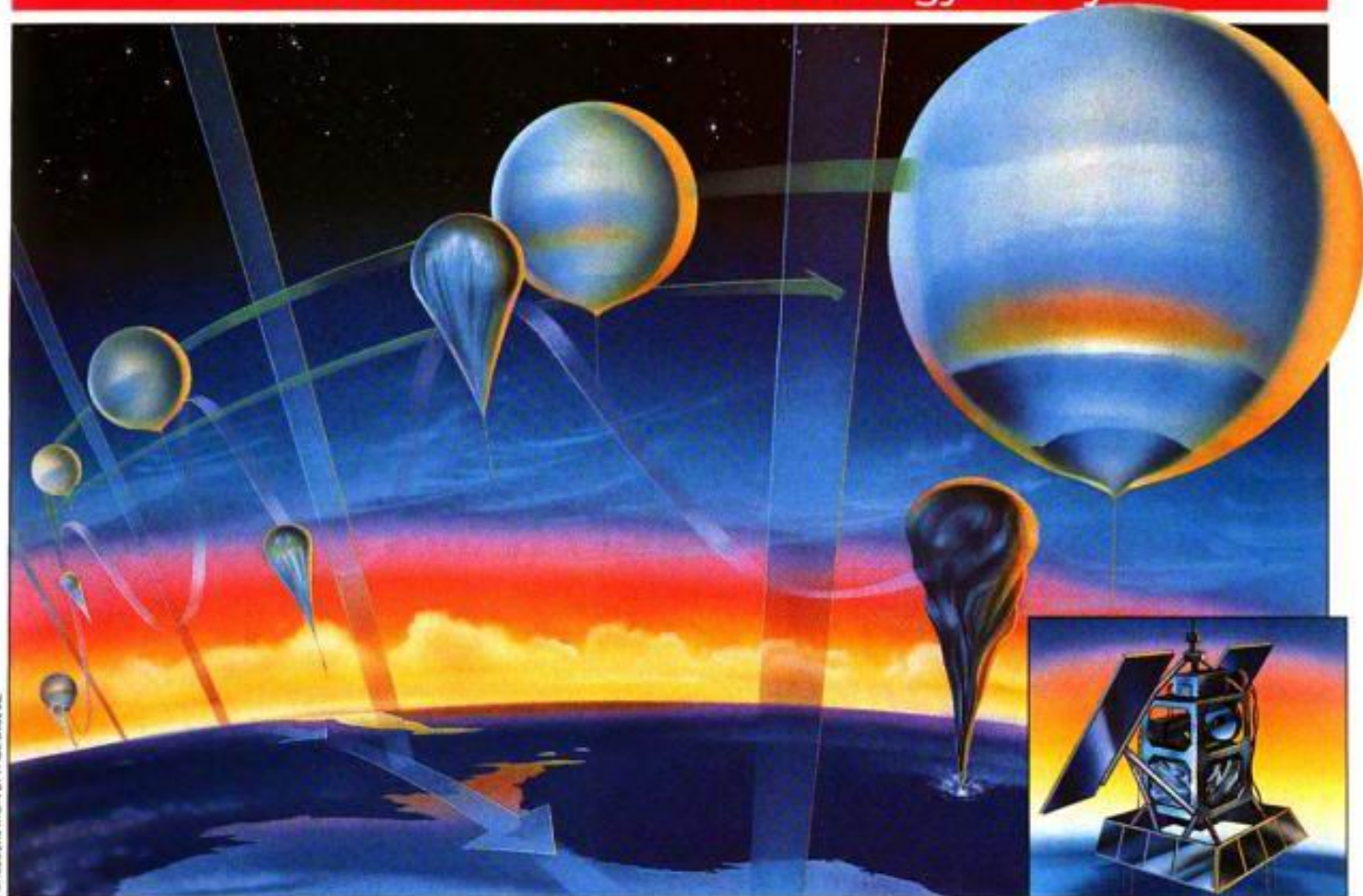
Highlights This Month

- **Joined Wings**—Heavy lift aircraft sport exotic designs.
- **Digital Sand**—Virtual reality helps generals plan battles.
- **Radiation Watcher**—Detector simulates a human cell.
- **Wall Climbing**—Decorations give rock fans a workout.
- **Executive Assault**—Pinstriped kin for Marine's Osprey.
- **Smart Goo**—Cold War secret gives crash dummy a brain.
- **Toner Trick**—Texas highway paved using toner fluid waste.
- **Cool Sounds**—Chilling a room with a loudspeaker's blare.

Editor/Writer: Jim Wilson
Reporters: Ken Cottrill, Fred Chesbro, Sarah Deem,
Stefano Coledan, Mike Fillon, Gregory Freiheer,
William Garvey, Evelyn Kanter, Mike Wallace

TECH UPDATE

News Of Tomorrow's Technology Today



Countdown Begins For Earth-Orbiting Balloons

GREENBELT, MD—"Superpressure" balloons now being developed by NASA will float several-ton payloads through the stratosphere on missions lasting more than three months.

The high-altitude balloons currently used by scientists, known as zero-pressure balloons, can lift 3-ton instrument packages to about 130,000 ft., but remain aloft for only a few days. They are launched partly inflated and expand as they rise. But after passing through the tropopause, where temperatures drop as low as minus-180°F, they vent most of their gas in the more than 70°F daytime temperature of the stratosphere. When the Sun sets, the remaining gas shrinks. In order to stay aloft, the balloon must drop ballast. As a result, most zero-pressure balloons survive no more than one or two sunsets.

Superpressure balloons are also

partially inflated when they leave the Earth. But unlike zero-pressure balloons—which have a venting hole in the bottom—superpressure balloons are completely sealed. This is possible because they are made of highly durable composite plastic and fabric materials that can withstand high internal pressures caused by solar heating. Maintaining helium at a constant volume and density also makes them extremely stable.

"Remaining aloft for months at a time, superpressure balloons will be

Because they retain virtually all of their original lifting gas, superpressure balloons will be able to circle the globe for months.

able to conduct astronomy, particle physics and ozone hole experiments that require both endurance and greater lifting capacity," says Jack Tueller, a balloon project scientist at NASA's Goddard Space Flight Center.

A full-size superpressure-balloon demonstration flight is scheduled for the summer of 1998. The first flight with a working payload could take off in January 2000.

Highlights This Month

- **MMX Muddle**—Lack of compilers delays software.
- **Beach Party**—Space robots show off at the shore.
- **Ancient Nile**—Ground-penetrating radar reveals river.
- **Solar In The City**—Unique home for green urban living.
- **Ultralight Jet**—Warbird engine mounts on a small wing.
- **Delta Devastation**—Rocket explosion creates acid cloud.
- **Robo Cigarman**—Vending humidor blends tech and taste.

Editor/Writer: Jim Wilson
Reporters: Fred Chesbro, Stefano Coledan,
Brian C. Fenton, Mike Fillon, William Garvey,
Andy Turnbull, Albert Watson

COVER STORY

KILLING ASTEROIDS



Once-secret data shows that Earth gets hit more often than we thought. Here is how we can blast the next killer rock from the sky.

BY MARK ALPERT; PM Illustration by Paul DiMare

● It's spotted by telescope on a clear night in October 2005. An asteroid nearly 1 mile wide is seen hurtling through space at more than 67,000 miles per hour. At first glance, it seems ordinary, very much like the thousands of other asteroids careening through our solar system. Except this one is headed straight for Earth.

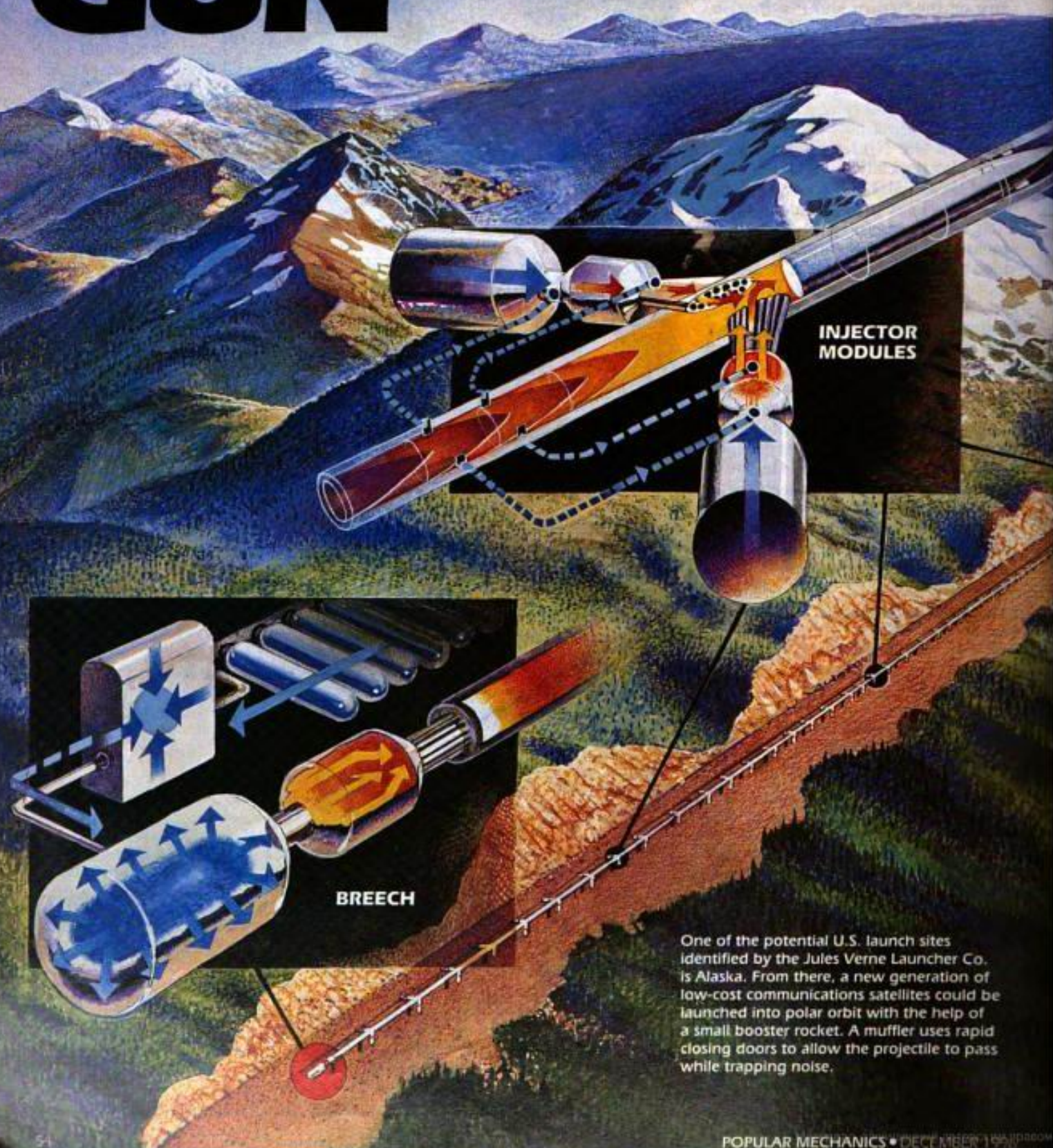
Astronomers check and double-check their figures, but the grim truth remains: The asteroid will hit within 24 hours. Panic spreads quickly. There isn't enough time to launch a rocket to intercept the speeding rock in an attempt to deflect or destroy it.

The killer rock strikes southern India with the energy equivalent of 1 million megatons of TNT. The cities of Madras and Bangalore are incinerated and millions are killed instantly. But the worst is yet to come. The impact kicks up billions of tons of dust. Much of it stays in the atmosphere for years afterward, blocking the sunlight and causing crop failures all over the world. As billions starve, the very survival of mankind is threatened.

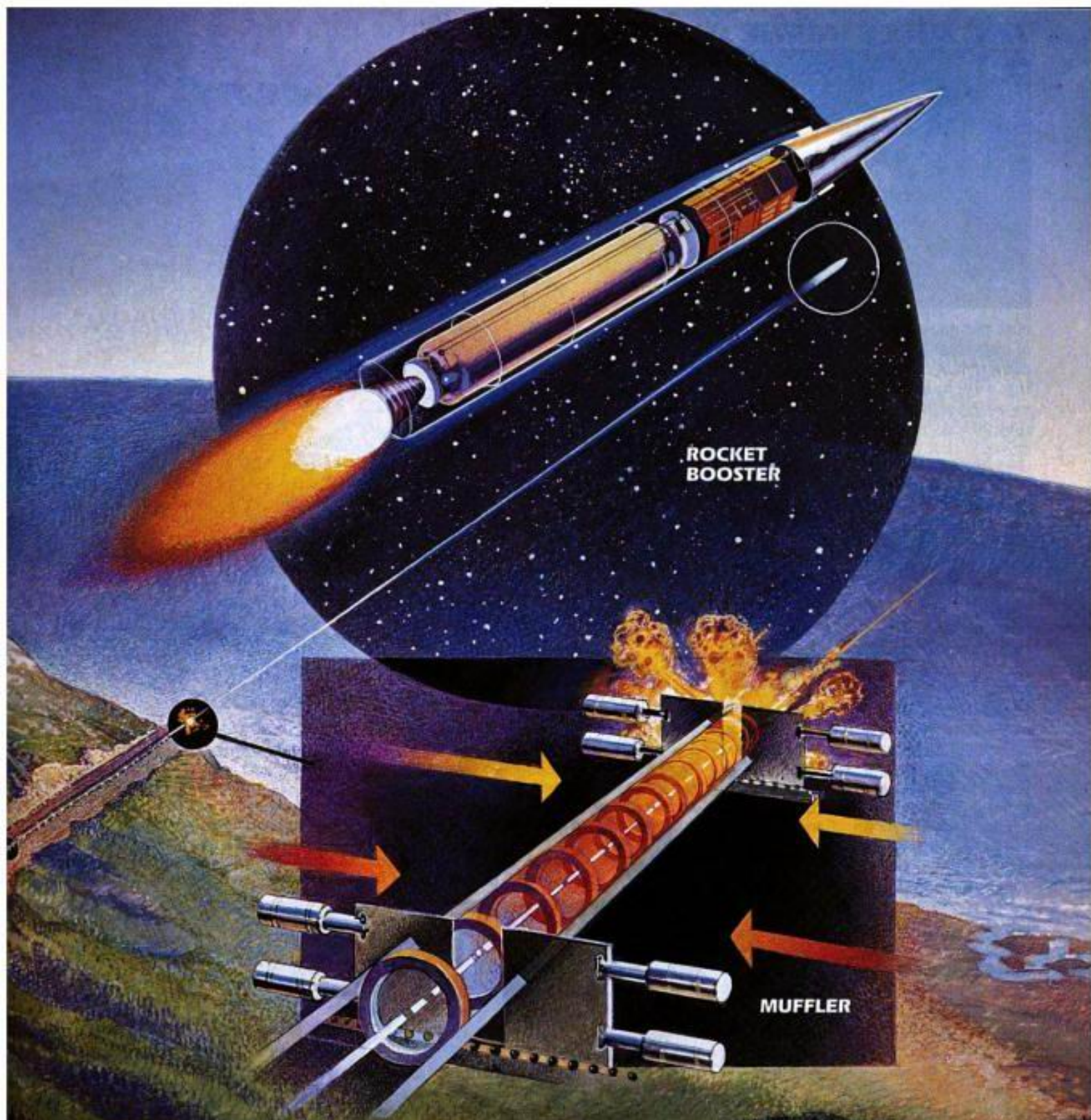


THE JULES VERNE GUN

An ambitious plan to change the way we launch satellites will fulfill the science-fiction writer's dream.



One of the potential U.S. launch sites identified by the Jules Verne Launcher Co. is Alaska. From there, a new generation of low-cost communications satellites could be launched into polar orbit with the help of a small booster rocket. A muffler uses rapid closing doors to allow the projectile to pass while trapping noise.



BY SCOTT R. GOURLEY, PM Illustrations by Harold Smelcer

● In his 1865 novel *From The Earth To The Moon*, author Jules Verne describes a post-Civil War society in which the convened members of the fictitious Baltimore Gun Club lament the sudden lack of artillery activities. Their boredom is soon broken by a speech from the club's president, who outlines a bold plan to use a giant cannon to fire a projectile to the Moon. One of the fictional club members awed by the plan is named Tom Hunter. Coincidentally, a very real visionary with the same last name may make author Verne's fantasy come true.

"Jules Verne was a true visionary in an era when you needed visionaries," explains John Hunter. "Now, the

problem is that we have too many visionaries and not enough doers." Hunter is standing in his cluttered Southern California office, where he has just drawn a diagram of comparative escape velocities on the blackboard. As president and founder of the Jules Verne Launcher Co., Hunter is combining Verne's vision with his own actions. Quite simply, he intends to use gas-powered launchers as an effective and inexpensive way of propelling satellites into orbit.

Hunter's quest began when he started working at Lawrence Livermore National Laboratory (LLNL) in 1985. One of his first projects at the lab involved the concept of an electromagnetic space launcher: "The

THE JULES VERNE GUN



SHARP TEST FACILITY

cost per joule of just about any kind of electric gun is so high that it's basically prohibitive," Hunter says. During a technical discussion at Livermore Lab, it was suggested that he look at the potential of "gas guns," systems that utilize a pump tube filled with heated and pressurized gas to drive projectiles at extremely high velocities. In fact, Hunter's search of the library database revealed that a NASA gas gun had achieved a projectile speed of 6.84 miles per second back in 1966. But he knew that higher velocity was needed.

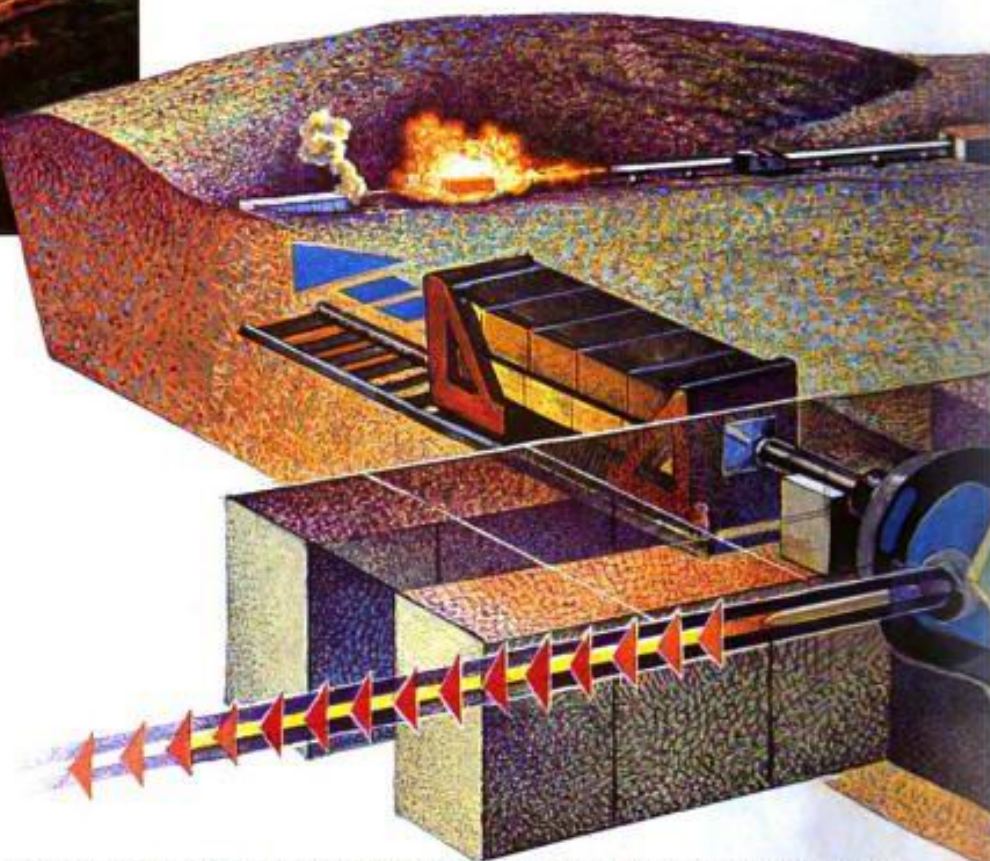
"At that point I knew, just like particle theory, that 99% of the people were just going along the well-worn path because someone had money or a cool idea. But they weren't being rigorous thinkers about solving the problem."

The solution that emerged involved the use of a gas gun with multiple injectors. Hunter's computer simulations suggested that such a system would work very well. "The velocities I was getting to were much higher than had ever been done before with conventional gas guns."

Hunter then conducted a 2-month lab project to demonstrate the anti-tank potential of a single-stage hydrogen gas gun operating at room temperature. "I got 1.5 miles per second. The results were within 1% of my code predictions on six data points." Based on the computer model's accuracy and the quick completion of the project, Hunter was funded for a 3-month effort to develop a 2-stage gas-gun precursor to a space launcher. The effort produced a 10-ft.-long gas gun that achieved a firing velocity of 5 miles per second.

"[That] still exceeds the velocity record for any rail gun ever built," Hunter says. "Gas guns routinely achieve 5 miles per second. That's what's so phenomenal about them. The beauty is that to access space, 4.35 miles per second is where the action really gets hot and heavy. At 4.35 miles per second, you can launch a 10-ton vehicle and get 33% fraction into LEO [low Earth orbit]. If you start with 11 tons, you're going to have 7275 pounds in LEO."

The success of the 10-ft. prototype



The SHARP firing sequence begins with the ignition of a methane gas mixture at one end of the steel pump tube. That explosion drives a 1-ton steel piston down the pump tube, which has been filled with pressurized hydrogen gas. The piston rapidly compresses the gas to 60,000 psi in the high-pressure section (below), destroying a coupling holding the projectile in the attached depressurized launch tube. The projectile is driven down the 4-in.-dia. tube at an extremely high speed and it bursts through a thin plastic sheet covering the end of the gun. All recoil forces are absorbed through the use of three sleds—two 100-ton sleds and one 10-ton sled—mounted on railroad tracks.



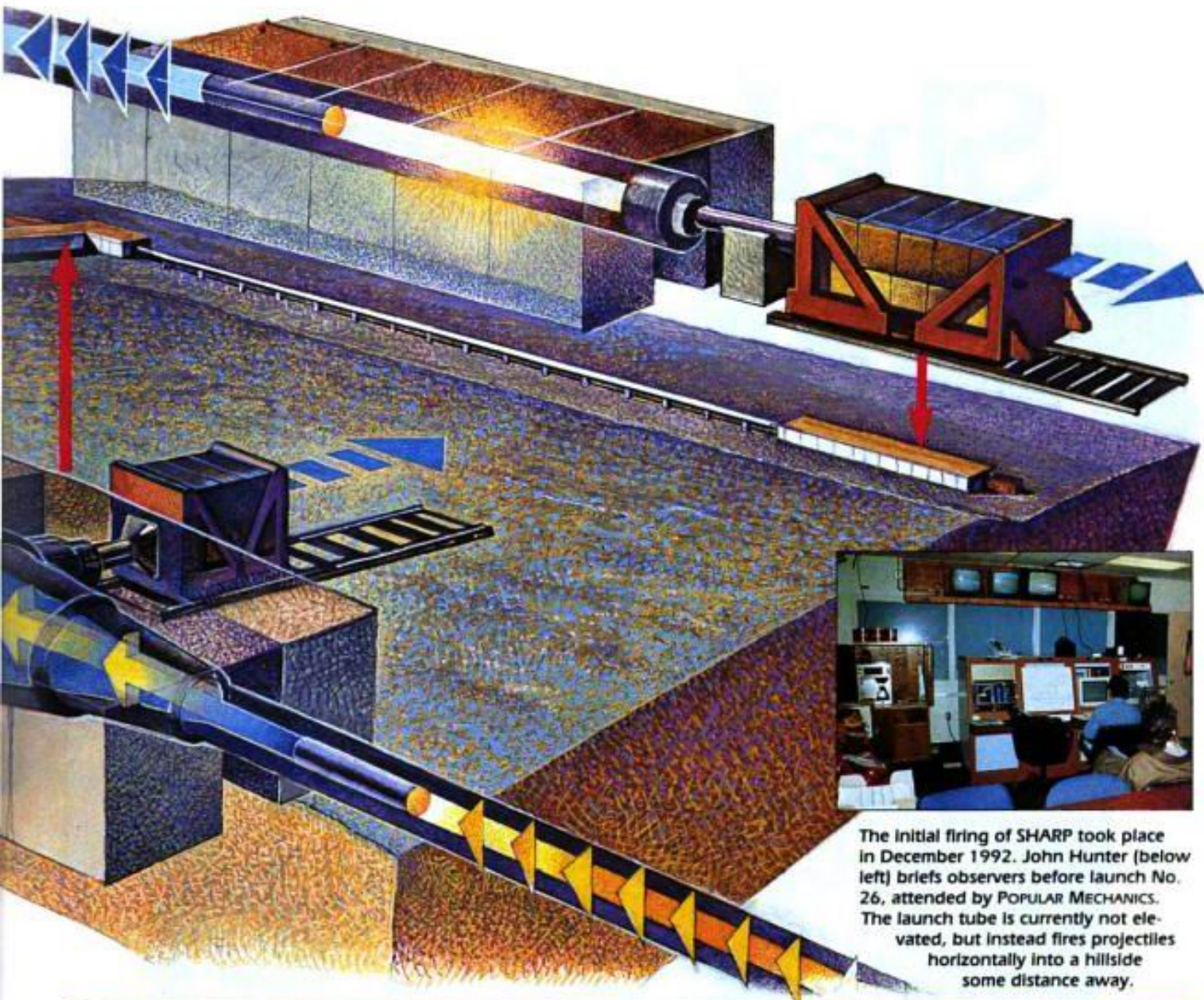
justified additional LLNL research and development funding for a "space gun" project identified as Super High Altitude Research Project, or SHARP. (Hunter chose the name in recognition of the U.S. government's HARP Super Gun project, which was conducted during the mid-1960s with standard powder technology.)

Located at LLNL Site 300, SHARP is the world's largest gas gun. The 425-ft.-long system was built in a unique L-shaped design with a 270-ft.-long combustion section and pump

tube mounted at a right angle to the 155-ft.-long launch tube. The original design was driven by a desire to minimize the height of any supporting gantry that would be required to elevate the tube for space launch.

"SHARP has only gotten to 1.92 miles per second because we're launching fairly big masses and we haven't jacked up the pressures very high," Hunter says. He adds that achieving the requisite 4.35 miles per second is "totally doable," based on both computer-model and lab-gun experience.

LINE PHOTO (LEFT) SCOTT GOURLEY PHOTO (TOP LEFT)



The initial firing of SHARP took place in December 1992. John Hunter (below left) briefs observers before launch No. 26, attended by *POPULAR MECHANICS*. The launch tube is currently not elevated, but instead fires projectiles horizontally into a hillside some distance away.



First, Hunter will build and fire a prototype system dubbed the "Micro Launcher." "Our Micro Launcher design is so small that you'll hardly see the projectile—maybe only 50 mils or one-twentieth of an inch," Hunter says. "That sounds crazy, right? I helped build the world's biggest gun," he says jokingly, clearly aware of the irony.

Hunter is also devoting considerable attention to the design of specially hardened satellite packages and has recruited experienced satellite designers for his team of engineers.

They will use the prototype systems to ensure satellite stability as it leaves the launch tube, as well as to address g-force hardening. The largest commercial guns will subject the satellites to 1000 g's for approximately 1 second. Although this is easily met by circuit designs, it may require hardening of components like solar cells or deployable antenna structures.

Based on SHARP experience, Hunter's engineers predict that the guns can easily be fired once per working day. Given a rate of 300

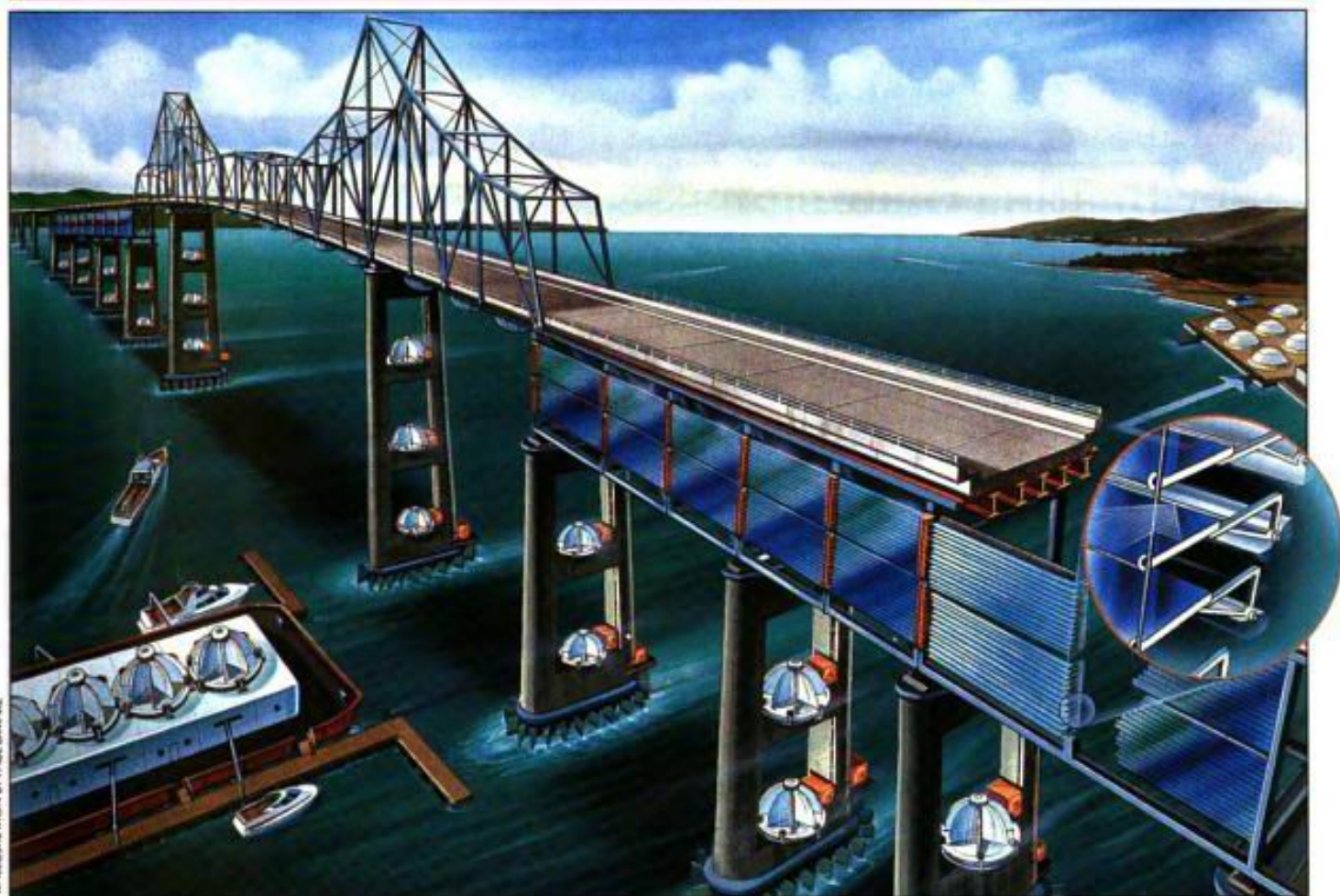
launches per year and a payload of 10,000 pounds per launch, the system has the potential of placing approximately 1500 tons a year into LEO. Moreover, at a target launch cost per pound of about one-twentieth of a modern rocket launch, the company estimates a breakeven point between the first 50 and 100 launches.

"The house odds wouldn't bet on us," Hunter says. "That's not a condemnation of house odds. That's just the way that the house works. But this is going to happen."

PM

TECH UPDATE

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PM ILLUSTRATION BY PAUL DIMARIE

Old Bridges Eyed As Future Fueling Stations

PORT EWEN, NY—If you live near water, you probably know of an old bridge no longer in use that looks like it's teetering on its last legs.

Where most people see rusting relics and eyesores that attract vandals, energy consultant Robert J. Dederick sees opportunities to free America from fossil-fuel dependence.

Dederick wants to convert derelict bridges into a network of free-standing energy stations. Similar to today's gas stations, they would sell nonpolluting fuels for the coming generation of zero-pollution vehicles.

Why bridges? Dederick says their locations typically make them perfect sites for solar panels and wind turbines. Bodies of water are notably lacking in obstructions that block the sun and wind. Bridges over fast-flowing streams or near shore areas are ideal anchor points for hydroelectric,

tidal-flow and wave generators.

Dederick's plan is to use the electricity generated by these nonpolluting devices to electrolyze water into its constituent oxygen and hydrogen. The oxygen could be bottled and sold locally to welders and hospitals, among others. The hydrogen could be used by cars that have been converted to run on the gas, or by fuel-cell-powered electric vehicles, such as future production models of Daimler's experimental NECAR II van (see

An artist's conception of the Jamestown Bridge in Rhode Island, after conversion into an energy station.

Tech Update, page 15, Oct. '96). In addition, when the technology arrives, it could be used in hydrogen-powered boats as well.

Facing dismantling bills that in some cases could equal or exceed original construction costs, bridge owners are taking Dederick's plan seriously. He says he is currently negotiating with five local and state governments.

Highlights This Month

- **Solar Speedboat**—Skimming the waves with solar cells.
- **Muscle Cars**—Student designers flex their imaginations.
- **Sub Recovered**—German U-boat floats to British dock.
- **Mine Blower**—Swedish robot explodes underwater killers.
- **Zapped**—Million-volt transformer built from circuit boards.
- **Farnborough '96**—Flubbed maneuver limits Russian jet.
- **Hingeless Helicopter**—Electric current bends blades.

Editor/Writer: Jim Wilson
Reporters: Sherri Eisenberg, Kathleen Gleaves,
Barry Rosenberg, Andy Turnbull

High-Stepping Heavy Haulers

FORT WALTON BEACH, FL—Tired of the endless debate that pits airlift versus sealift? A retired aeronautic engineer has patented a cargo-transport concept that blurs the distinction.

Much like a conventional hovercraft, the vehicle uses powered lift to reduce hydrodynamic drag during takeoff. Fans blow air into a below-hull space flanked by pontoons and retractable doors fore and aft. When the vehicle reaches liftoff speed, the aft door retracts and the hovercraft fans cut off. The effect is to nose the machine skyward like a seaplane.

Once airborne, the craft's lifting-body fuselage and stubby



Hybrid ground-effect transporter is based on inventor's homebuilt craft (left).

wings put its aerodynamic center of lift at the same point as its center of gravity. This coincidence makes for stable water-to-air transitions and—combined with the flat, low-aspect-ratio wings—allows

the vehicle to travel efficiently in ground effect.

Inventor Chuck Bixel says he has demonstrated the concept with small radio models. These have flown on higher cushions of air than equivalent models of other ground-effect vehicles.



CHUCK BIXEL PHOTO

Containers For People

VALDEZ, AK—A lesson from the *Exxon Valdez* disaster: Have trained personnel available for immediate and extended deployment. But where to house them? In emergencies, crew populations can double or triple quickly, outstripping the berthing facilities aboard spill-response vessels.

In the past, that has meant expensive renovations to a ship's superstructure. But now there's

Bubble Your Troubles Away



Flow boiling whisks heat from avionics modules recently designed at Purdue University.

The flowing liquid flushes away these bubbles—along with the hot vapor they contain—and leaves room for new bubbles to form. The process dissipates far more heat than simple air or liquid cooling. Boilermaker engineers have proved the concept on lab-built avionics modules.

WEST LAFAYETTE, IN—What do nuclear reactors and computers have in common? Both must stay cool, because meltdown means disaster. Now a single technology, developed at Purdue University, could chill machines big and small—from microchips to megawatt lasers.

Called flow boiling, the technique forces liquid through microchannels carved into heat-producing devices. The heat boils the liquid, causing tiny bubbles to form on the microchannel walls. The



PURDUE PHOTOS



MARINE INDUSTRIES N.W. PHOTO



TECHNICAL MARINE PHOTO

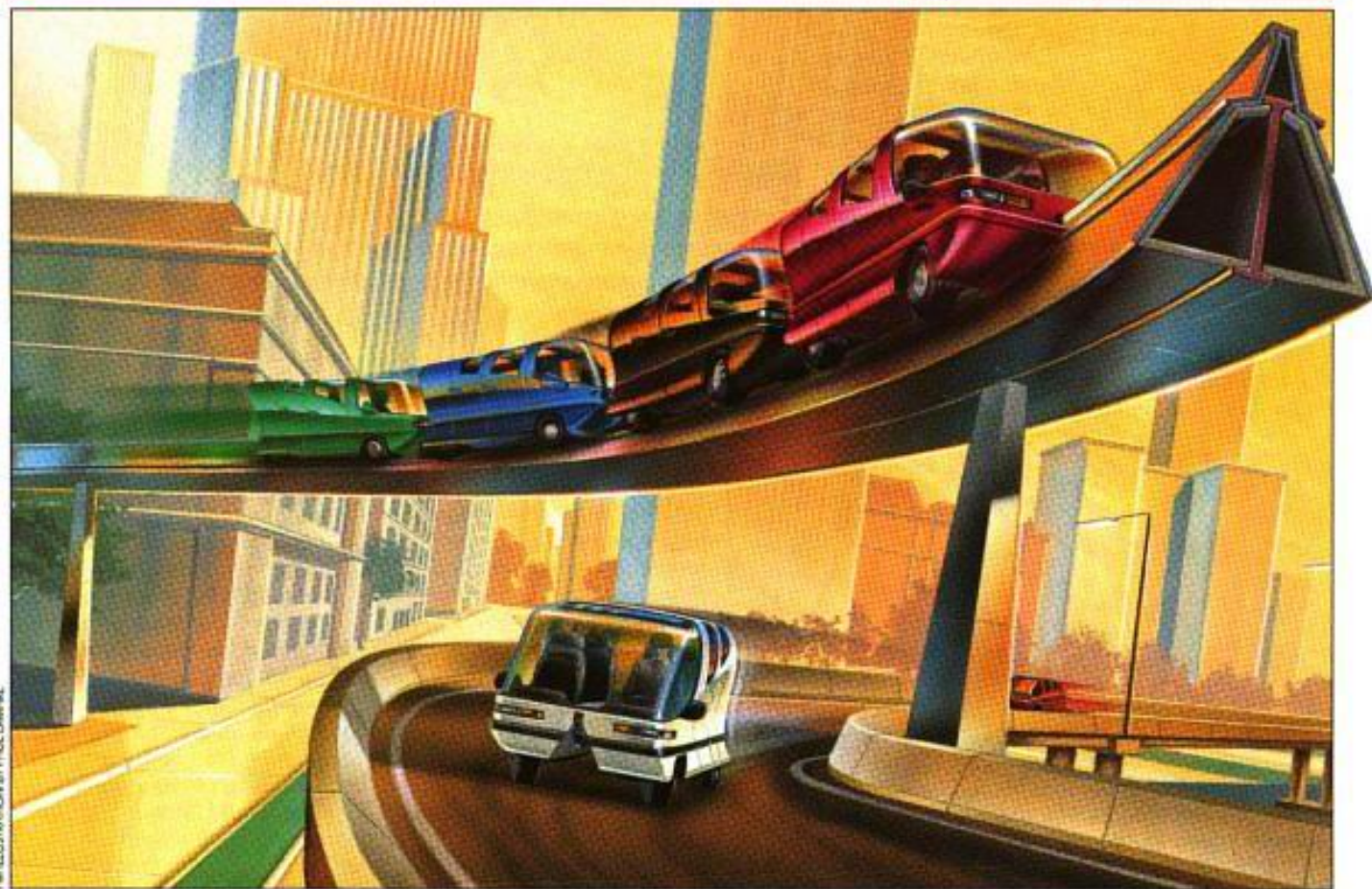
Oil-spill contingency barge can house expanded crews in portable modules.

a simpler solution: portable crew quarters, developed by Marine Industries N.W. Inc. The modules, which match the dimensions of inter-model containers, lock to a vessel's deck with standard corner fittings.

A berthing module sleeps six and contains a shower and mudroom. A galley/utility module can double as a recreation area during slack time—or as a planning center during emergencies. Meanwhile, a command and communications module features four windows.

TECH UPDATE

News Of Tomorrow's Technology Today



Rapid Transit Rides Rails, Then Roams Roads

RØDOVRE, DENMARK—There's your car. Then there's public transport. Few would argue that one can replace the other, even in the big city. But efficient as they are, subways and rail lines won't take you door to door. And cars, for all their convenience, clog urban arteries and cloud the air with their emissions.

Could one mode of transportation offer the best of both worlds? Danish inventor Palle R. Jensen thinks so. His proposed system, known as RUF, is an electric commuter vehicle, at home on rail and road alike.

On the streets, a RUF car could tap on-board batteries to travel for roughly 30 miles. This modest range should be enough to get the vehicle to an access ramp leading onto a network of monorails. At the ramp, the elevated rail dips to the ground so that vehicles can climb aboard.

A triangular slot in the belly of the car matches the cross section of the monorail. The slot houses four small support wheels and two drive wheels that press against the rail to scoot the vehicle along. Once on track, the car picks up power from the rail and returns it via regenerative braking. It enjoys unlimited range, speeds up to 125 mph and hands-off control.

Because the cars' front and rear ends fit together, multiple vehicles can platoon to form chains heading for a common destination. This serves

RUF slot cars can gang into trains while on the monorail, or wander the streets alone, powered by on-board batteries, to minimize air resistance.

For trips out of town, the car's slot can be plugged with a small diesel generator and a fuel tank.

Jensen points out several cost advantages. The rail is a standard I-beam cloaked with steel plates and concrete. And automakers could mass-produce the vehicles to RUF standards, for purchase by both the public and private sectors.

Highlights This Month

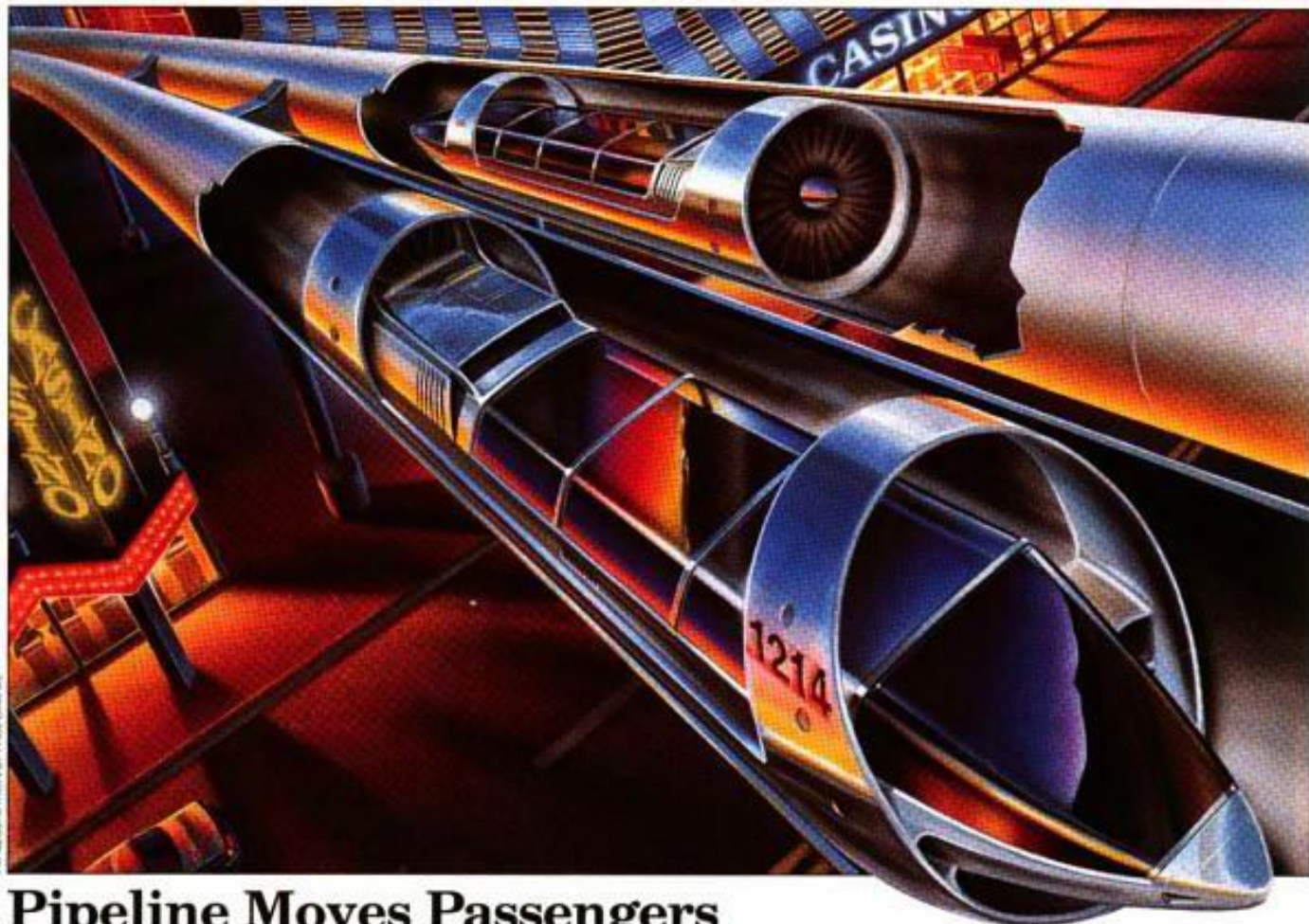
- **Cyberbrew**—Japan's virtual-reality beer makers.
- **Happy Returns**—Introducing the reusable X-34 rocket.
- **Water Bearer**—Radical hybrid sealer concept.
- **Shell Shocked**—Army's electronic artillery zapper.
- **MDTV**—Telemedicine network to debut in Georgia.
- **No Holds Barred**—Bionics revive paralyzed hand.
- **Rock Rollers**—Robotic vehicles wheel through mine.

Editor/Writer: Gregory T. Pope
Reporters: Philip Chien, Jim Dunne, Mike Fillon,
Kathleen Gleaves, Scott Gourley, Barry
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Herb Shuldriner, Andy Turnbull

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TECH UPDATE

News Of Tomorrow's Technology Today



Pipeline Moves Passengers In Ground-Effect Machines

LAS VEGAS, NV—Cross a levitating train with a hovercraft, send it flying through a tube and what do you get? The unique vehicle that Levitated Transport Systems is proposing.

True, engineers have long raised hopes for pneumatically suspended transit vehicles. The attraction of such systems echoes the appeal of magnetic levitation: efficient transport without wheel friction.

But the Air Cushion Transport System (ACTS) boosts the concept to a new level. ACTS combines pneumatic suspension with lift from aerodynamic ground effect. Curved to match the lower arc of its enclosed tubular guideway, an ACTS vehicle starts out riding a pillow of air that's ingested by a fan in its nose. Meanwhile, a rear variable-pitch propeller gets the car moving.

Once it has gained sufficient speed, the car slips into ground effect. Mounted above the craft's main body, two large rings act as airfoils to suspend the vehicle. The rings, along with the semicylindrical body itself, create a circumferential air buffer between the car and the tube's inner walls, enhancing stability.

As the ACTS vehicle whistles through the tubeway, valves open and close to regulate air pressure, vent

In one proposed application, air-cushion vehicles operate in ground effect as they whisk gamblers between casinos.

out exhaust and supply breathing air.

Although the technique is unproven, ACTS appears to offer a number of advantages, particularly speed. Running in ground effect within the controlled environment of a tube, the vehicles require little power to reach impressive velocities. The ACTS concept covers cargo transport, moderate-speed people movers and 300-mph intercity passenger service.

Highlights This Month

- **High Hand**—Spacewalking robot to aid astronauts.
- **Spy In The Sky**—Satellite monitors missiles, sees stars.
- **Special Operations**—Remote surgical microvehicles.
- **SEAL Machines**—New commando speedboats.
- **Shore Thing**—Flexible reef to fight beach erosion.
- **Plane By Train**—Shipping an entire airliner body.
- **Gear Splitting**—Stepless transmission comes of age.

Editor/Writer: Gregory T. Pope
Contributors: Philip Chien, Chris Chinnock,
Mike Dillon, Rick Schrader, Herb Shuldiner

RECREATIONAL VEHICLES

PALACES ON

New from road to roof, big motorhomes pack more power, convenience and luxury for royal-class touring.

BY CLIFF GROMER, Contributing Editor



● The blackness slowly yields to a purplish blue outlined by a crimson orange tinge. An image starts to take shape through the windshield, a vista absolutely awesome in its magnitude. You can't buy a home with a view like this because they don't build houses on the edge of the Grand Canyon. Yet here you are, enjoying this amazing place amid all the comforts of home.

But this home is different. It specializes in scenes you can't buy. Or vistas that would tax the resources of a millionaire—if views like this were even for sale.

You take in this panorama pampered by luxury surroundings—plush leather furniture, plank kitchen floors, tiled bathrooms, cabinetry of rich wood that is skillfully crafted. The temperature is controlled by constant hot-water heat and central air conditioning. A big-screen TV complements a high-end home-

entertainment center. Open the big side-by-side freezer/refrigerator and the icemaker has a ready supply of cubes to chill your drink.

Push a button and 15 ft. of wall and floor extend out, instantly opening up 45 sq. ft. of additional living space. Call it life in the spoiled-rotten lane, if you will, but it's what the newest motorhomes have to offer.

Class A motorhomes start with an in-house-built or outsourced chassis that the manufacturer, or coach-builder, uses as a base for the body. Prices range from about \$30,000 to more than \$250,000. The ultimate Class A's are big touring buses that feature monocoque construction. The builder basically finishes off the bus' bare shell. The ante to step into one of these babies begins at more than a half-million bucks, and goes up to something on the order of the space shuttle. We don't cover

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WHEELS



Holiday Rambler Navigator 400 rolls by the red rocks of Sedona, Arizona, where the cost of a building lot exceeds that of the motorhome. This luxury coach comes with full-leather seats and sofas and plenty of cabinet space. Features include on-board washer/dryer, central air and constant hot-water heat. Cockpit has excellent ergonomics. The electronically controlled 6-speed automatic transmission shifts via touch pad on left console.

PALACES ON WHEELS



COACHMEN DESTINY



Destiny comes with marble-tile flooring and hardwood cabinets.



ITASCA SUNCRUISER



Slide-out opens up additional living space at the push of a button.



Large freezer/fridge runs on LP or electric.

the buses here because unless you're a John Madden or Loretta Lynn, you probably won't be buying one.

The big news in Class A motorhomes can be summed up in a word—more. More power, room, comfort and safety. Entry models still come with gas engines up front, but the drawbacks are an extended front-end, heat, noise and reduced space if the engine is brought inside the coach under an access cover. The trend in the medium and large models up to 40 ft. long is the use of a diesel pusher. The rear-mounted engine minimizes noise and heat, and doesn't intrude on living space.

Until now, the problem with many diesels has been the lack of



Kitchen offers homelike convenience.

power. At the controls of a 30,000-pound motorhome, you had to bury the throttle and wait what seemed like years for your speed to pick up. But Cummins Engine Co.'s new



Bath features stall shower and dressing area.

M11-440E, available on Holiday Rambler's top-of-the-line Navigator 400, changes all that. With 400 hp and 1350 ft.-lb. of torque, this 38- to 40-ft.-long coach takes off like the family car.

Tight maneuvers in a huge motorhome can be a challenge. So Oshkosh, a chassis supplier to several leading coachbuilders, is engineering a 4-wheel-steer chassis to make steering a little bit easier. The chassis will debut on Winnebago's flagship Luxor model this spring. Chassis makers also are incorporating big-truck features, such as air-ride suspension, antilock brakes and engine-braking systems.

Widebodies measuring 102 in. are supplementing the standard



Basement model stows luggage under the floor like a bus.



FIRAN EUROPREMIER



Europremier is available in eight different floor plans and offers a forward-facing couch, as well as a second television in the bedroom.



Cummins' 400-hp diesel has best-in-class power.

96-in.-wide coaches, but they're not yet legal in all areas. A slide-out—where about a 15-ft. section of the body is mounted on a sliding electric/hydraulic chassis member that extends from the coach when it's parked—is one way to increase living space. Multiple slide-out sections are also in the cards, but they'll depend on the GVWR of the chassis.

Basement-model motorhomes are becoming increasingly popular. They

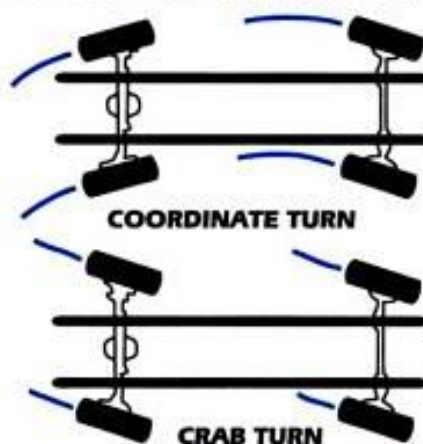
have raised floors with storage compartments underneath, like the luggage compartments on buses.

On the styling side, there's no doubt that the flat-faced bus look is in. A wedge front takes up to 3 ft. of livable space—and renders it unlivable. And the bus look makes even a low-line coach appear more expensive.

Inside, central air conditioning is replacing roof-mounted units that tended to blow down on you. The a/c air-unit mounts in one of the basement storage compartments, lowering the coach's center of gravity while giving it a cleaner roofline.

Appliances? Sure, you get the kitchen sink, but some motorhomes also have a washer/dryer unit and a central vacuum-cleaner system.

Behind the wheel, you get an entirely different perspective. Switches and controls have come under the scrutiny of the ergonomic engineers, and you sit so high up, the vehicles in front of you look like Matchbox cars. You can see ahead for miles. Big coaches, like the Navigator 400 we tested in Arizona, are surprisingly easy to drive. The ride is soft, but not

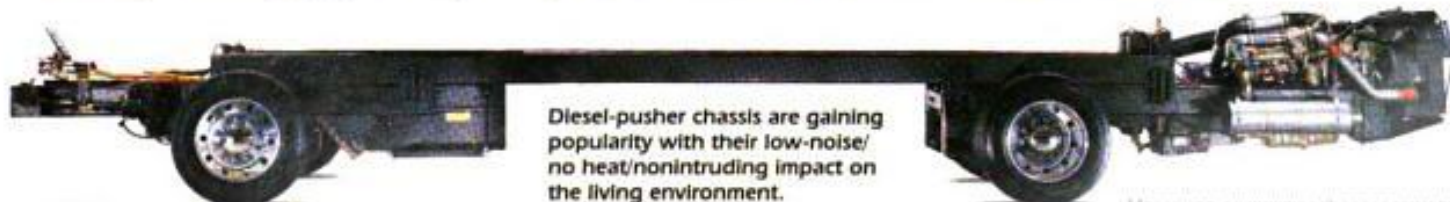


New 4-wheel-steer chassis by Oshkosh will ease tight maneuvering by large coaches.

overly mushy, and you can spend hours behind the wheel and feel no fatigue.

And when it's time to pull into an RV park or a scenic area to rest for the night, you know there will be no surprises awaiting you like in some no-tell motel. You simply walk back to your comfortable queen-size bed and spotless bathroom.

In fact, the new motorhomes make getting there so much fun, you may not want to come back. **FM**



Diesel-pusher chassis are gaining popularity with their low-noise/no heat/nonintruding impact on the living environment.

TECH UPDATE

News Of Tomorrow's Technology Today



PM ILLUSTRATION BY PAUL DIMARE

Future Ships Could Swim Like Fish

LAWRENCE, KS—Fish have known it for 400 million years: The easiest way to slice through water is to flap a tail. Now man is catching up. Seeking efficiency and stealth for marine craft, engineers are looking seriously at fishtail propulsion.

At the University of Kansas, Ronald Barrett has already demonstrated a 9-in. proof-of-concept vehicle. Wiggling at a frequency of 22 swipes per second, a submerged tail drives the little model at 0.6 knots. The motion comes from piezoelectric ceramic strips, which expand and contract in response to an alternating current. Lined up at 45° angles along the tail's sides, the strips can

be triggered independently to control pitch, yaw and roll.

Barrett sees two major applications for what he calls solid-state aquatic vehicles. Navies could exploit noiseless propulsion and fishlike behavior to have small underwater robots sneak up on hostile ships. Surface vessels could take advantage of the drag-reducing eddies touched off by the oscillating tail, for a big boost in efficiency over conventional screws. Scaled up, a 100-ft. tail could push a ship at 30 knots.

Meanwhile, Massachusetts Institute of Technology engineer Michael Triantafyl-

Editor: Abe Dine
Assistant Editor: Gregg Pope
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Bob Scheier

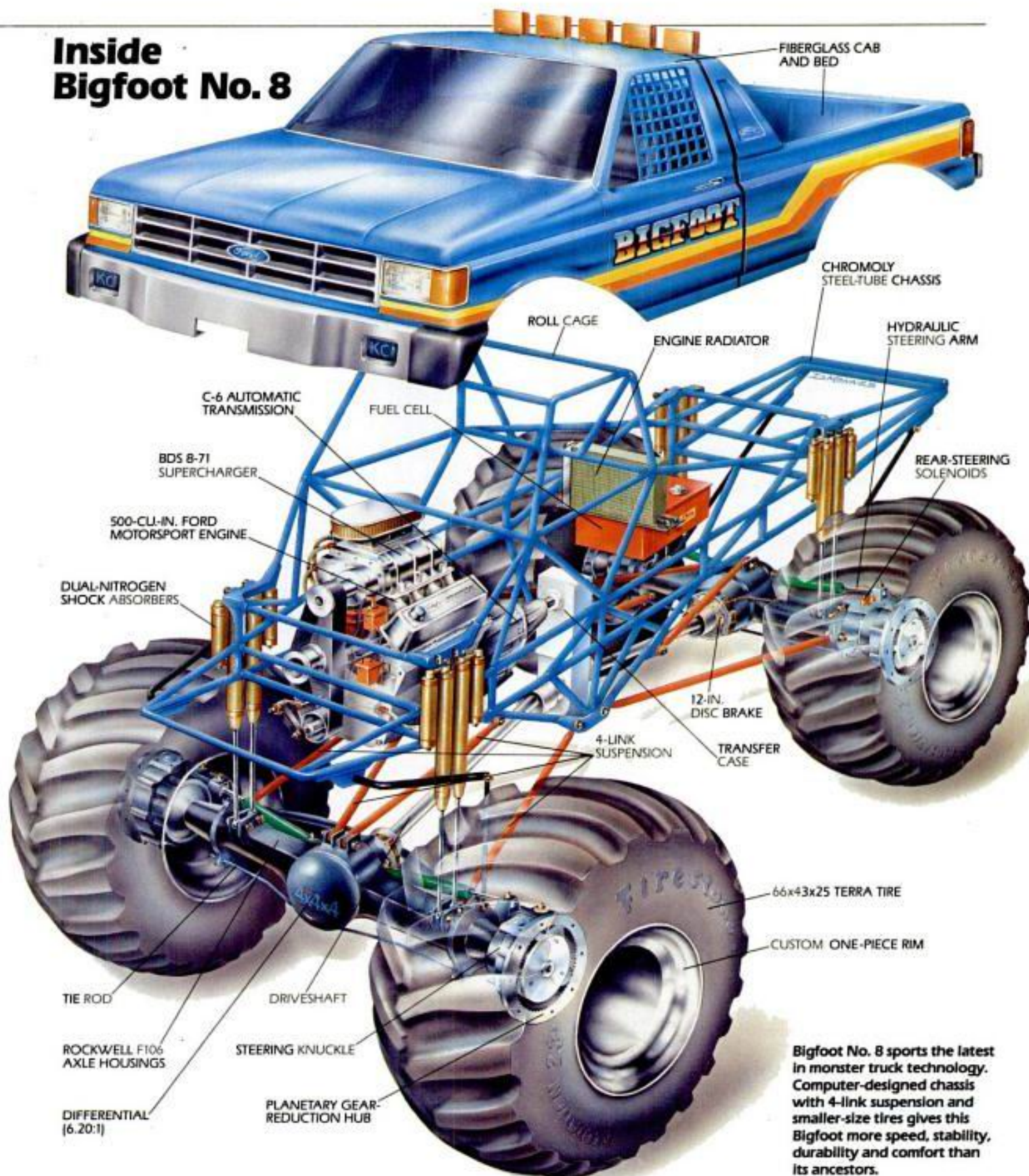
lou is already designing a 5-ft. robot sub with a tail that is driven by hydraulically activated pulleys.

Twin piezoelectric fishtails, oscillating out of phase to minimize yaw, could drive future tanker.

Highlights This Month

- **Water Bearer**—Floating aqueduct could slake California drought.
- **Weather Eyes**—Planes' new sensors spot wind and see through storms.
- **Grand Slam**—Army's superdoor is faster than a speeding bullet.
- **Jets Strip Jets**—Water guns peel paint from aircraft.
- **Shot From The Blue**—Huge gun to launch payloads from barge.
- **Armed Forces**—Robot limbs evolve for strength and grace.

Inside Bigfoot No. 8



Bigfoot No. 8 sports the latest in monster truck technology. Computer-designed chassis with 4-link suspension and smaller-size tires gives this Bigfoot more speed, stability, durability and comfort than its ancestors.

housings (normally used in school buses), replacing 5-ton military axles as the hot setup. Bigfoot mechanics cut the ends off the housings and weld on special flanges. The axle itself (an industrial application), comes with a planetary gear reduction on the end of the shaft.

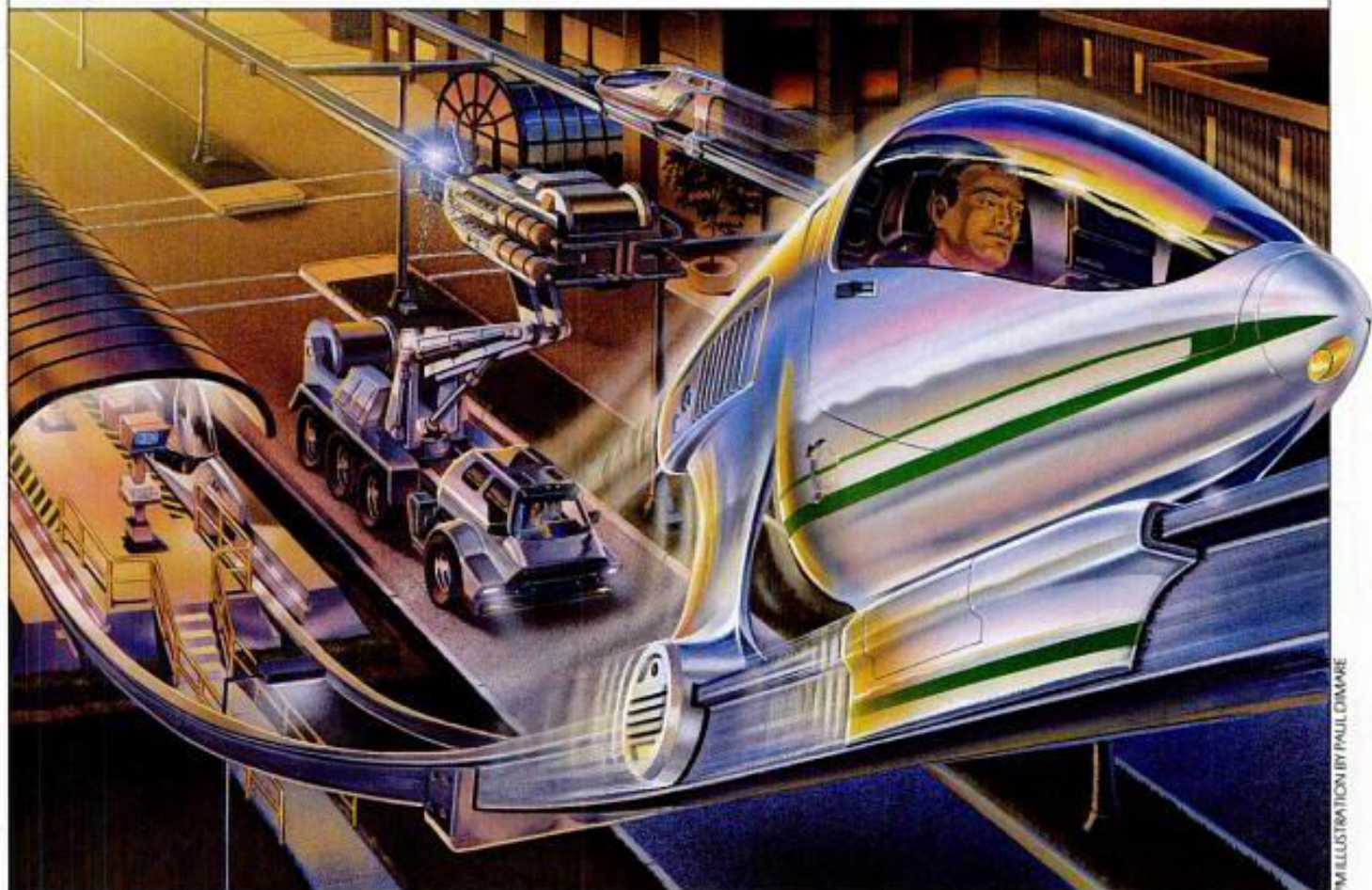
This setup allows additional 3.56:1

gear reduction to ease the torque load on the axle. The shafts are cut down and resplined to fit the F106 carrier. The conventional axle-mounted drum brakes were sent to the trash bin to cut unsprung weight. So Bigfoot's mad progress is controlled by a 12-in. disc brake mounted on the differential pinion shafts.

Custom-made one-piece rims (safer and lighter than 2-piece rims) carry 66x43x25 Firestone Terra tires. In the real world, these tires have the dubious distinction of supporting 30-mph liquid fertilizer spreaders. On Bigfoot, they're pushed to speeds of 70-plus mph. Inflated to between 5 and 11 psi, the tires, about \$2000

TECH UPDATE

News Of Tomorrow's Technology Today



PM ILLUSTRATION BY PAUL DIMARE

Personal Maglev, Public Transportation

IRVINE, CA—How do you get Southern Californians out of their cars and into mass transit? It may take an ingenious marriage of convenience and efficiency. Prolific inventor Doug Malewicki has a solution: individual magnetic-levitation cars that run on a grid of monorails.

Each teardrop-shaped vehicle, called a People Pod, would carry one or two passengers and operate under the supervision of a master traffic-control computer. The rider would hop in a Pod at a drop-down station, key in the destination and sit back for the ride. An on-board computer ushers the vehicle around the 1-sq.-mile grid for a nonstop 100-mph

ride. Meanwhile, the master computer routes idle Pods to high-traffic areas and controls Pod-spacing density.

Built of aerospace composites, a Pod would weigh only 200 pounds, including superconducting magnet. The vehicle could gain power for levitation and propulsion from the track via an induction pickup.

For safety, anticollision radar would activate hydraulic brake pads that squeeze each side of the T-shaped track. A healthy Pod could nose a failed vehicle into a maintenance track to clear congestion.

Editor: Abe Dane
Assistant Editor: Greg Pope
Contributors: Philip Chien, Mike Fillon

Malewicki is currently jockeying for funds to build a 1-mile test track in Orange County, California.

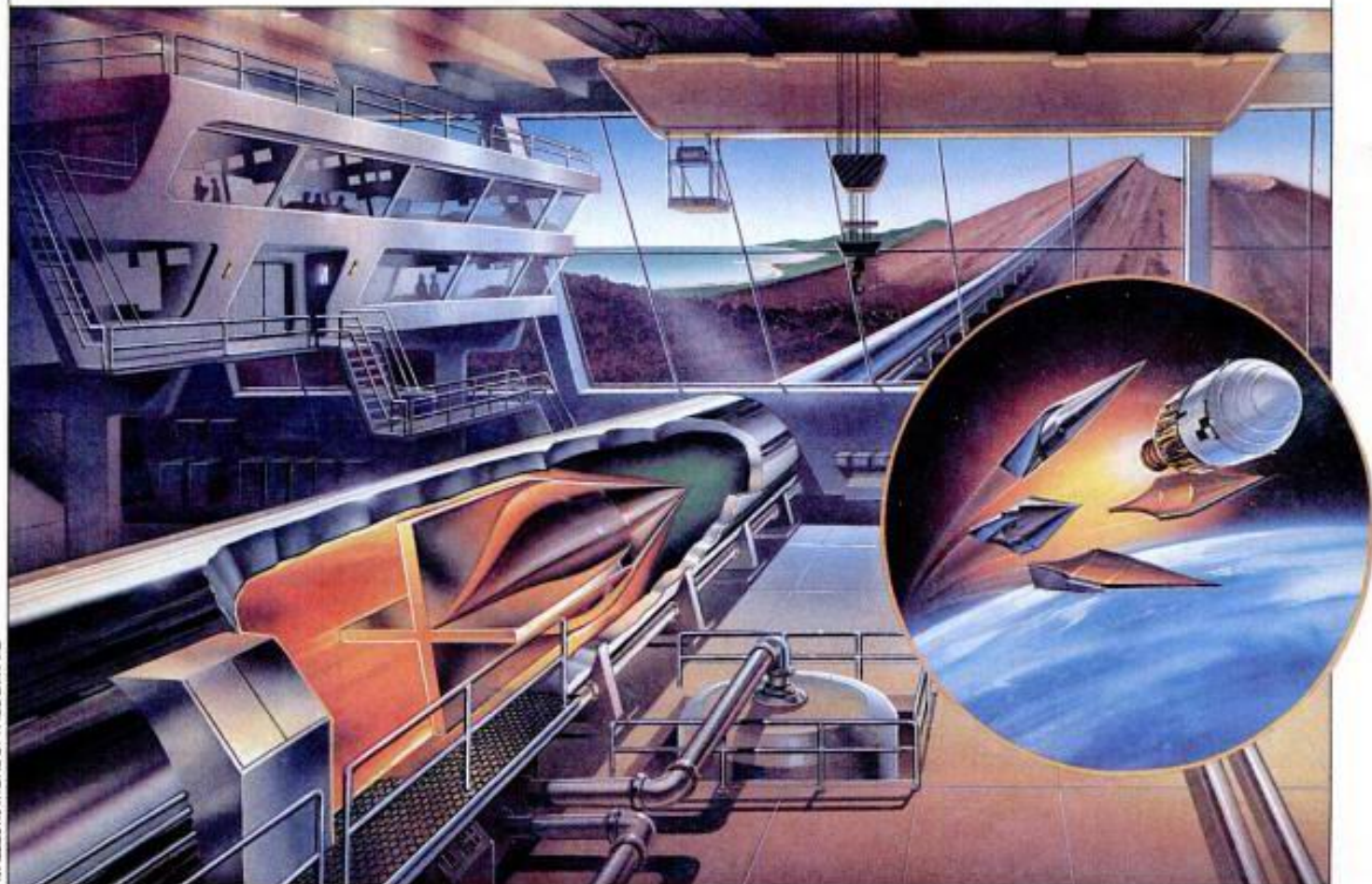
One key to People Pod economics: roll-forming machine, in background, lays steel track across utility poles.

Highlights This Month

- **Fly Me To Mars**—Boeing's excursion vehicle flouts lunar-lander tradition.
- **Jet Packer**—Japan's magnet-drive ship is ready.
- **Weight Lifter**—C-17 takes to the skies in maiden flight.
- **Special Forces' New Horses**—Night choppers emerge from shadows.
- **Fastest Guns In The West**—Bullets fly at 27,000 miles per hour.
- **Six Of A Kind**—A half-dozen drones vie for close-range role.

TECH UPDATE

News Of Tomorrow's Technology Today



PM ILLUSTRATIONS BY PAUL DIMARCE

Hypersonic Scramjet Cannon Aims For Orbit

MOORPARK, CA—Streaking through the stratosphere at Mach 10, the National Aero-Space Plane will rely on scramjet engines to burn fuel in air that's moving at supersonic speeds. Engineers now want to harness the same principle in a giant cannon that could jolt payloads into orbit cheaply.

The future launch system would feature a Scramaccelerator—the most ambitious in a family of devices known as ramaccelerators.

Ramaccelerators all work on the same premise: A tube several miles long contains a mix of fuel and oxidizer. At one end stands an injector, such as a gas gun, which fires a projectile into the tube at

roughly 1000 miles per hour.

As the projectile races through the tube, the fuel-oxidizer mixture slips between its sides and the inner face of the tube. Shock waves touch off supersonic combustion of this mixture. Expanding combustion gases push against the projectile's afterbody, boosting it to speeds greater than Mach 15. At the tube's end, the projectile pops through a diaphragm and shoots into space.

Research began at the University of Washington, but is now worldwide. A Scramaccelerator prototype

is currently undergoing tests with 5-ounce projectiles at NASA contractor Advanced Projects Research, Inc.

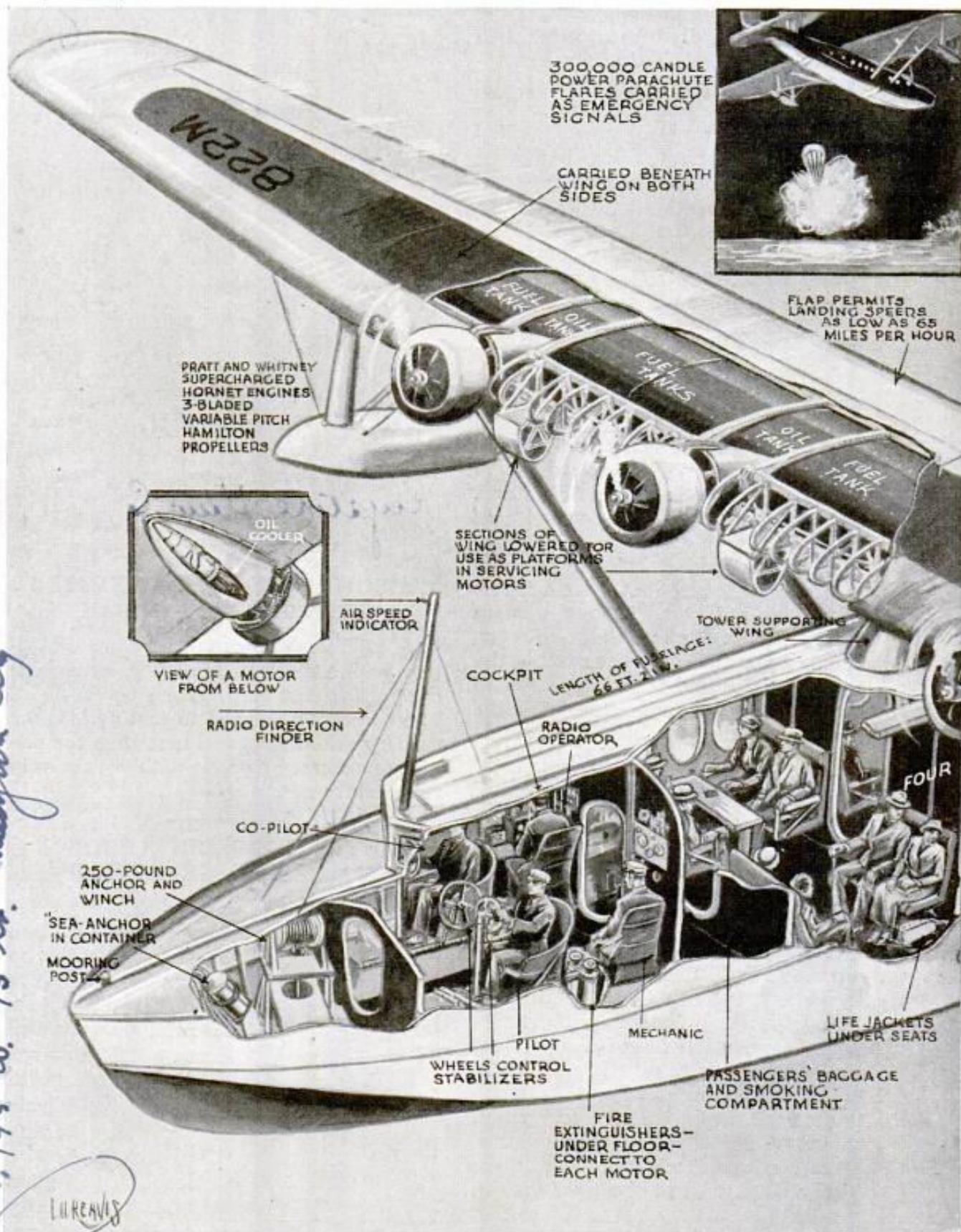
Heat-shield-enshrouded space payload gains hypersonic momentum as gases ignite behind it in Scramaccelerator.

Highlights This Month

- **World's Smartest Bat**—Winged submunition hunts down moving tanks.
- **Eye On The Storm**—Camera scopes out tornadoes from space.
- **Being There**—Virtual-reality games for chemists and arcade jocks.
- **Air Rockets**—Future missiles convert to ramjets.
- **Mine Reader**—Airborne infrared scanner spots buried explosives.
- **Ship Of Tools**—Navy's newest floating oceanographic laboratory.

Editor: Abe Danc
Assistant Editor: Greg Pope
Contributors: Philip Chien, Mike Filon,
Oliver Fultz

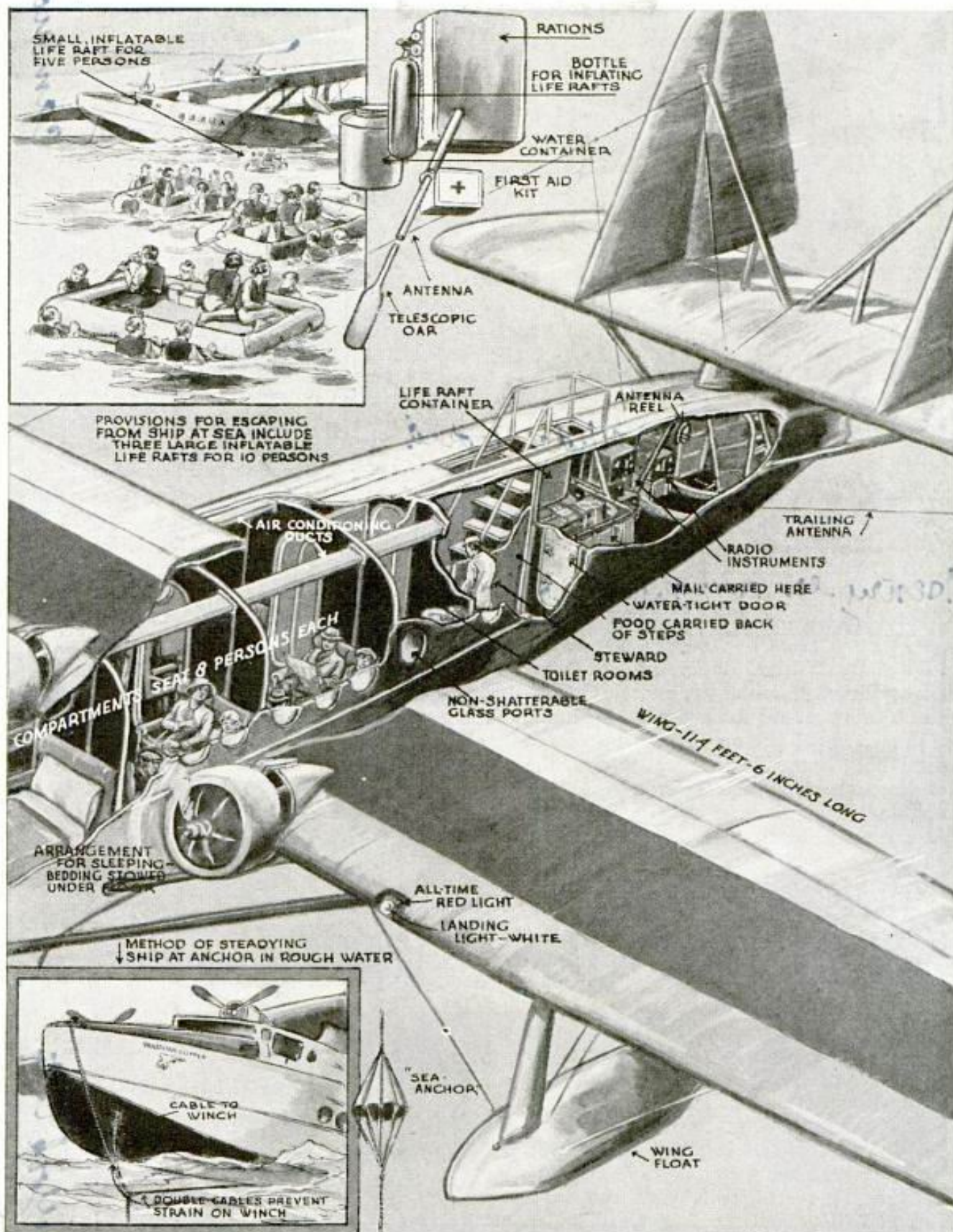
Giant Plane To Cut U. S.-Argentine Time



Flying Time between the United States and the Argentine Will Be Reduced by Two Days When the Giant Sikorsky S-42, Speedy Clipper Plane Goes into Service; Four Engines, Rated at 3,000 Horsepower, Drive the Loaded Ship at Speeds in Excess of 155 Miles per Hour

LUREN

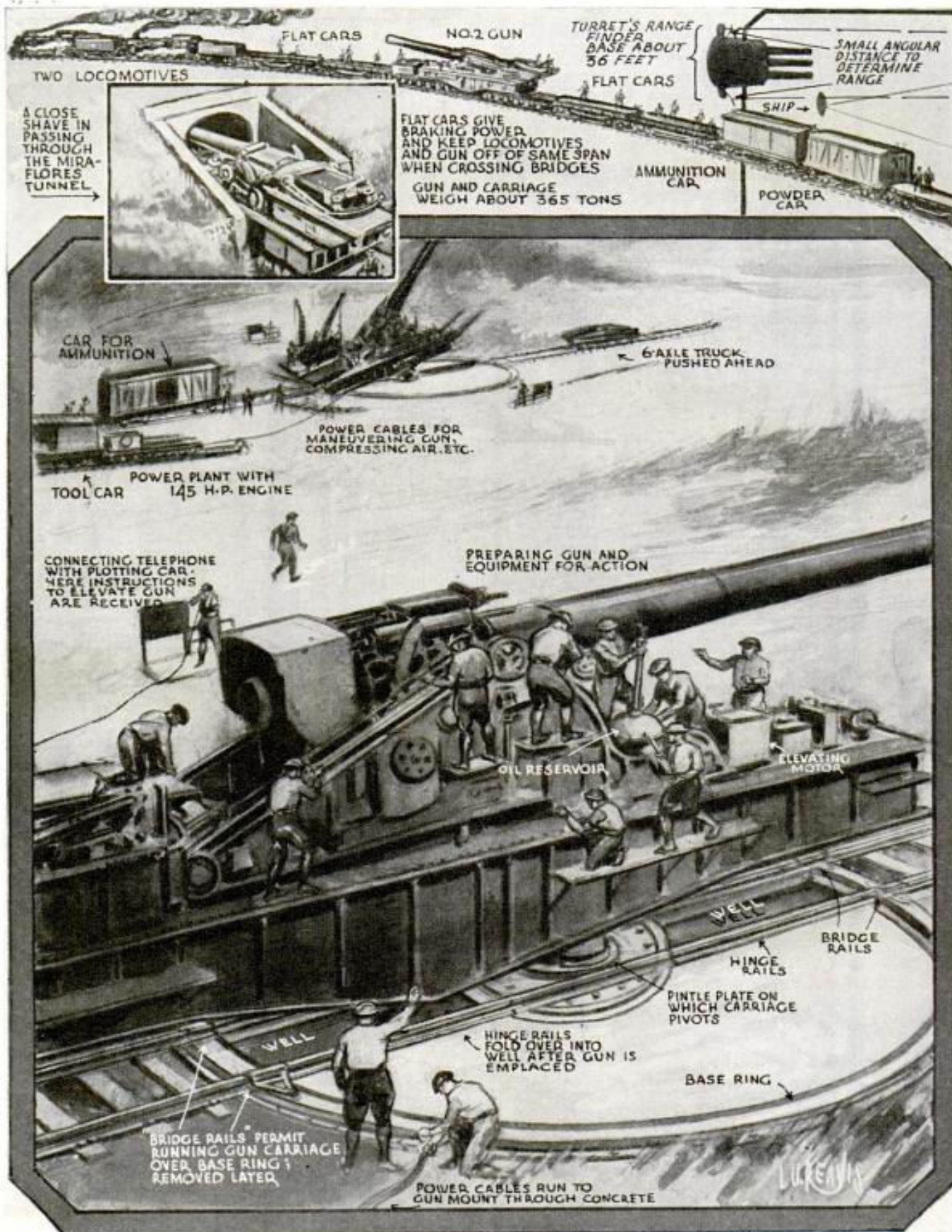
Air Clipper Seats Thirty-Two Passengers



Greater Safety for Ocean Air Service Is Offered by the Giant Sikorsky S-42, Which Carries Thirty-Two Passengers and 2,000 Pounds of Cargo, Including Mail; Low Landing Speed, Powerful Emergency Flares, Inflatable Life Rafts, Radio and Special Anchors Are Some of the Safety Features

Logan U. Adams
145 W. 45th St.
New York City

Gun-Train Guards Ends of Panama Canal

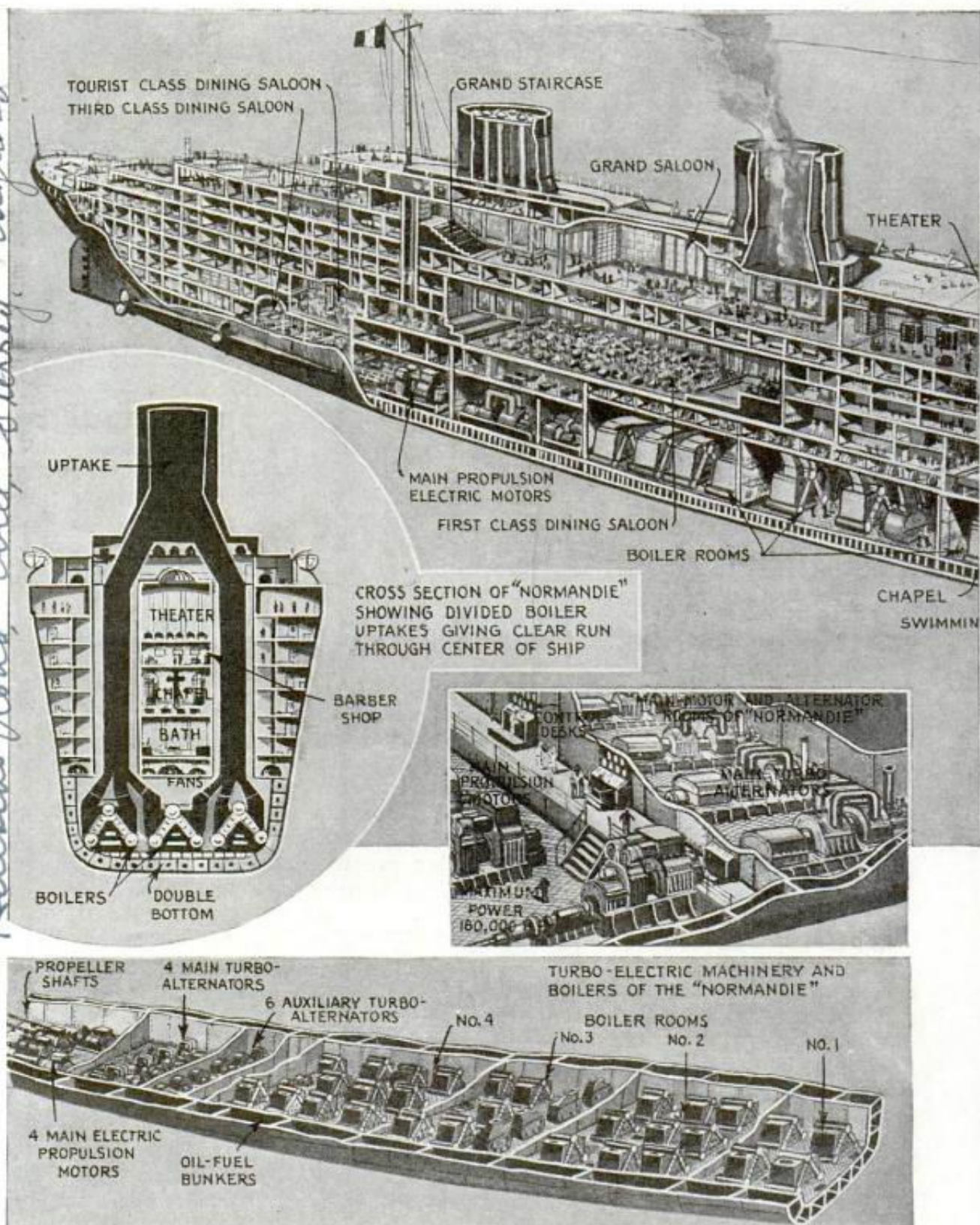


Mounted on a Train for Fast Transportation from the Atlantic to the Pacific Coast, Large-Caliber Guns Guard Both Ends of the Panama Canal; Drawings Show How Big Gun Is Mounted After Trip across Isthmus; Manned by 200 Men, the Rifles Fire from the Rails; Full Turn Permits All-Round Firing

D 1022

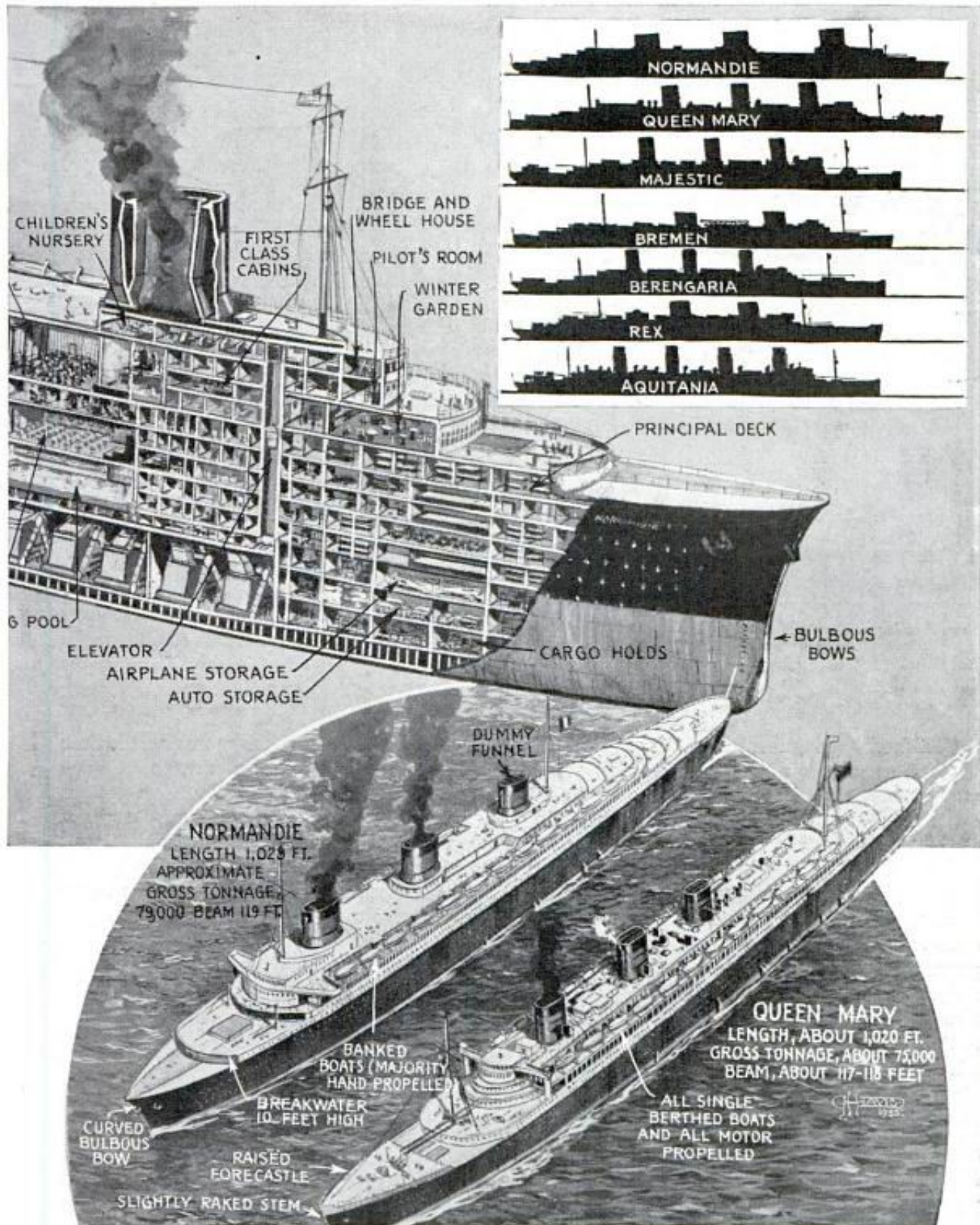


'Normandie' a Marvel in Speed and Comfort



Top, Cross-Section of the "Normandie," Which Set Speed Records on Both Crossings of the Atlantic; Center, Left, How Boiler Uptake Is Split to Give Clear Run through Center of Ship; Center, Right, and Bottom, Details of Powerful Plant Which Produces 160,000 Horsepower to Give the Luxury Liner Speeds of Thirty to Thirty-Five Knots; "Normandie" Boasts the Utmost in Comfort for Passengers; She Has Fourteen Elevators, a Grand Foyer Three Decks High, the Largest Swimming Pool Afloat, Theater, 1,100 Telephones, Cabins with Private Terraces, Formal Garden and Night Club

Luxury Liner Driven by Giant Electric Motors



Top, Right, Comparative Sizes of Ocean Liners, with "Normandie" Largest, 1,028 Feet Long; Bottom, Sketch Comparing "Normandie" with "Queen Mary," British Liner Being Groomed for Her Maiden Voyage; Note That "Queen Mary" Is Only Eight Feet Shorter Than "Normandie"; the British Ship Boasts Single-Berthed Lifeboats, All Propelled by Motor, While "Normandie's" Lifeboats Are Banked and Mostly Hand Propelled; an Advantage for "Normandie" Is Claimed in Curved Bulbous Bow, Compared with Slightly Raked Stem of "Queen Mary"; the Ships Are Latest Entries in the Atlantic Speed Race

Popular Mechanics Magazine

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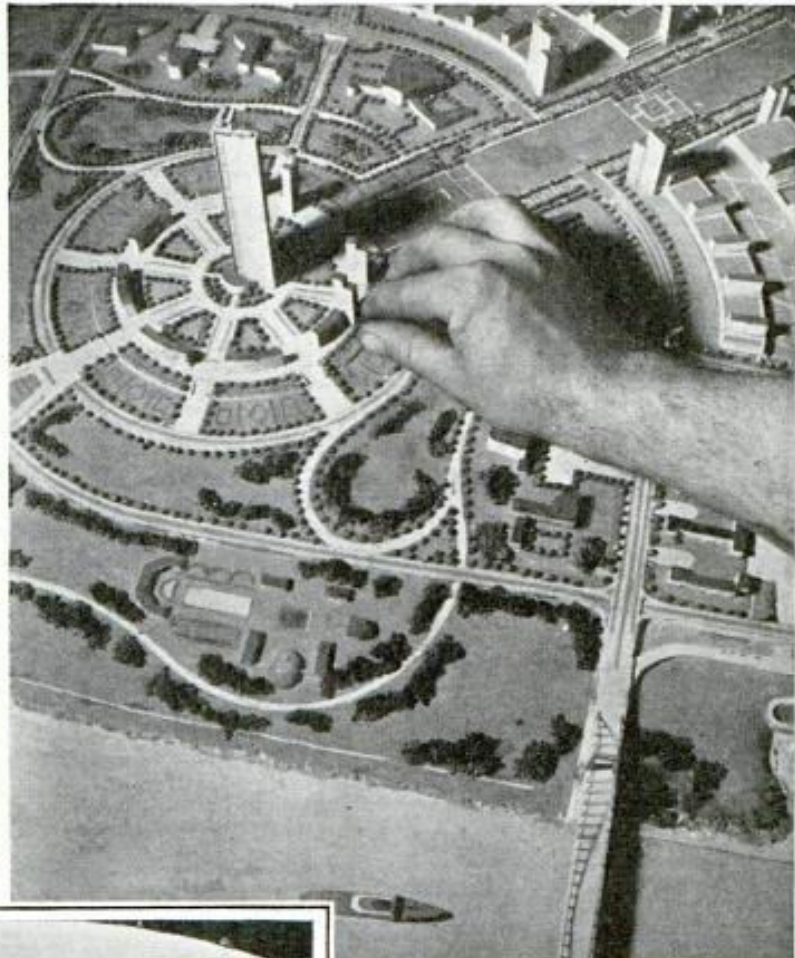
WRITTEN SO YOU CAN UNDERSTAND IT

Vol. 71

MARCH, 1939

No. 3

H 1524 *The* CITY *of* TOMORROW



501 Madison Ave. New York



Views of model from which Democracy is being constructed in 200-foot Perisphere at New York World's Fair

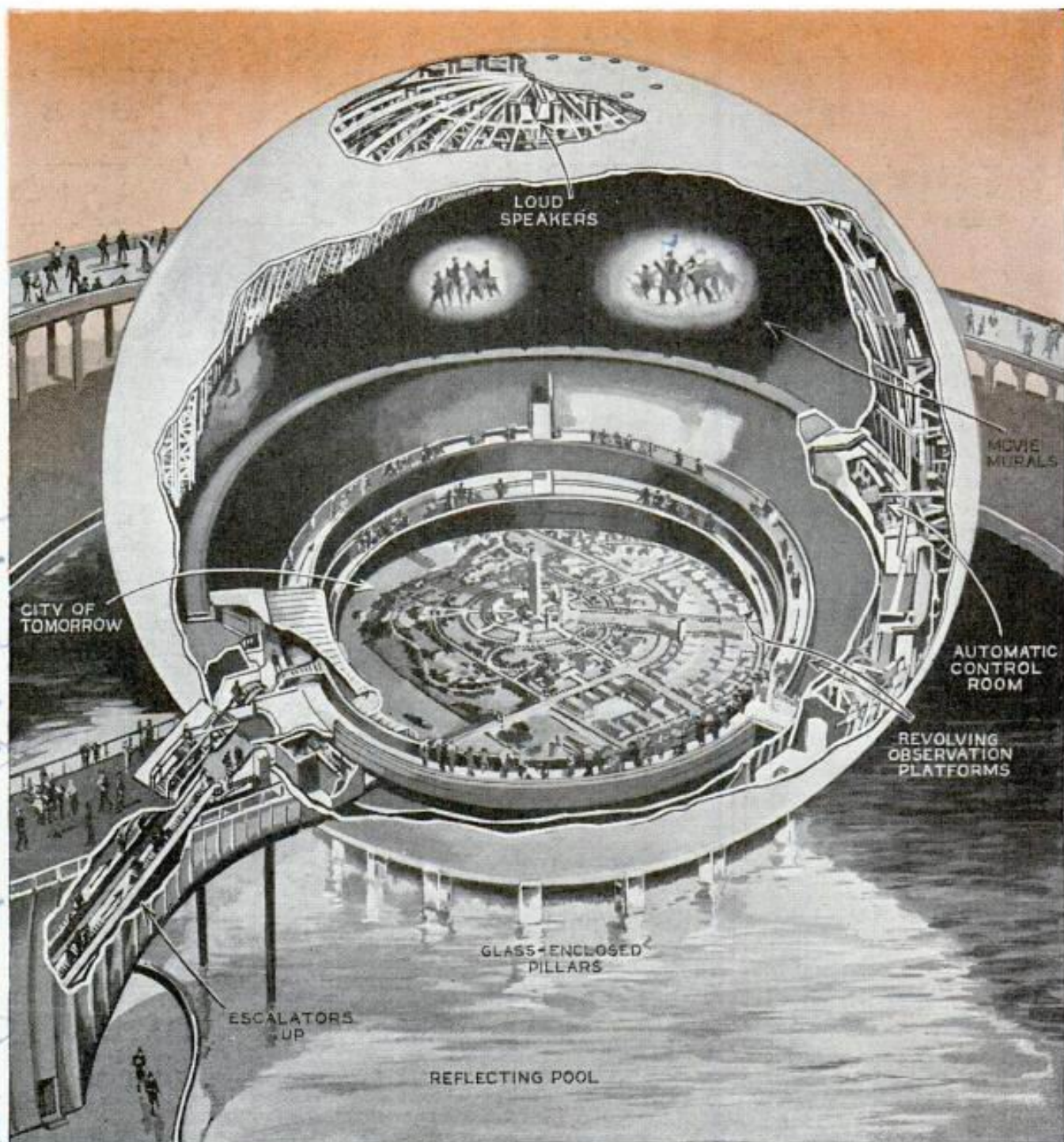
By Henry Dreyfuss
Industrial Designer

As Told to Julian Leggett

THE city of tomorrow is going to stretch and take a deep breath and be a healthier and happier community because of that. It will be composed of a central town or "brain center" surrounded by satellite towns containing factories.

People who work in these factory towns are going to live close to their

141524



Drawing of Perisphere with photo of 200-foot model of Democracy as it will appear to World's Fair visitors. Henry Dreyfuss is creator of the fair's theme exhibit, the central feature of which is Democracy, planned community of tomorrow

work. They will have a school and a movie. The resident of the satellite town will get up in the morning in a house pleasantly surrounded by green. He can walk to work and his children can walk to school in complete safety because they will never cross a vehicular street. When his wife goes to market, she can walk if she wishes, through a park, and she will shop in a park, since the stores will be situated around pleasant

green belts. She might drive, but she never would run the risk of killing anyone because no one will cross the highways.

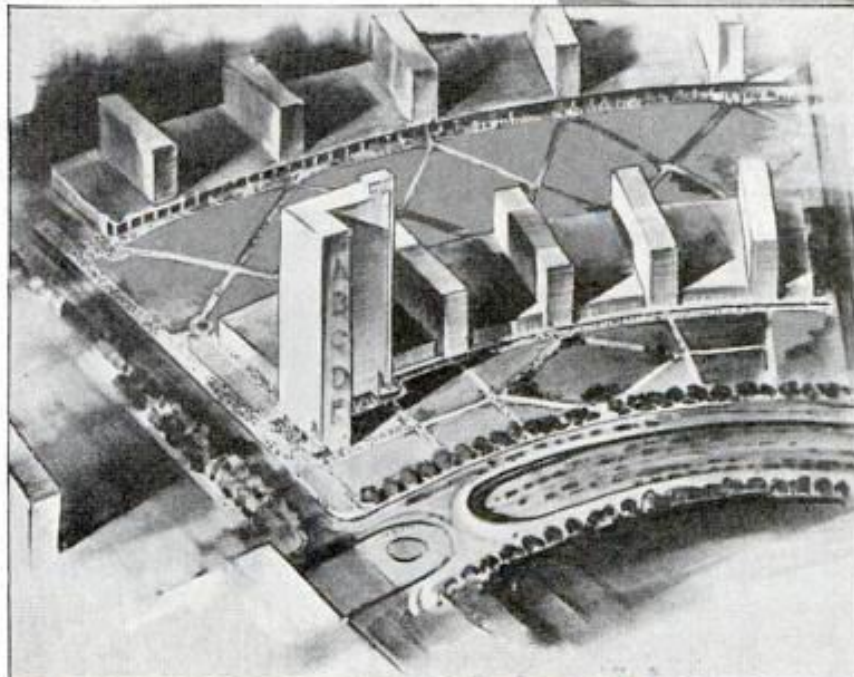
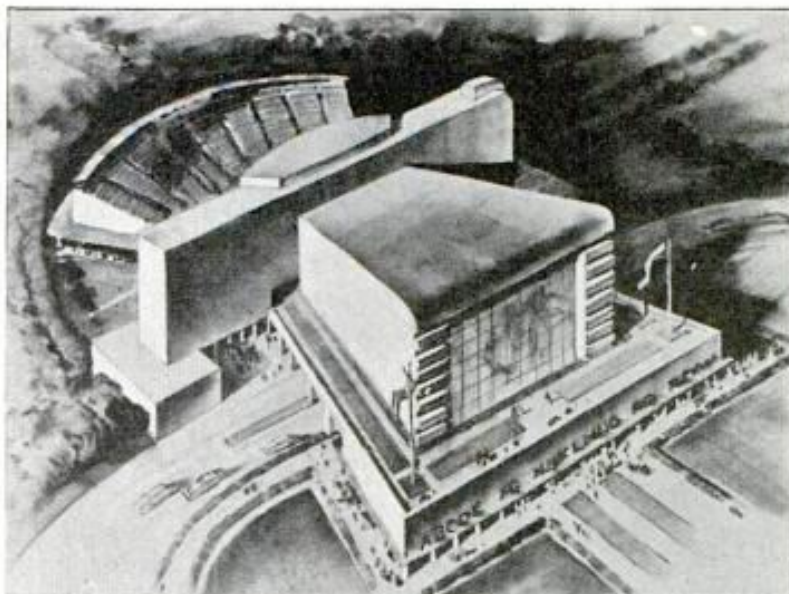
If this couple wants to hear the latest theatrical production, they will drive forty miles to the hub—to Democracy—over pleasant highways and right to the theater without a single traffic jam, because the city is planned for that very thing. They will park under the theater, see the per-

formance in air-conditioned comfort, then return home.

Their home, in the satellite town, will have a living room, bedroom and dining room facing a park, and a kitchen facing a highway. It will be painted in attractive colors—an individual house that will resemble no others on the street. The park facing the home will have a place to swim, and playgrounds for the children.

In the satellite town there will be a public market where the farmers living in the green belt will bring their produce. People will not eat concentrated food capsules; they will eat fresh green foods direct from the gardens. They won't have artificial flowers because they will get fresh ones from the garden. The family will develop good taste because they will be surrounded by good things—music, trees and other cultural advantages.

A man will be loyal to his employer because he makes this city possible. Today a man leads two lives—the life of his work and the life of his family. Tomorrow's city is



Top, Democracy's opera house, designed by Henry Dreyfuss, has reversible stage facing open-air amphitheater in summer and interior of theater in winter. Center, model of open-air restaurant. Bottom, shopping center of Democracy, as sketched by Theodore Kautzky

going to inject a third stage, which is playtime to improve his mind and body. The man of the future will be sufficiently educated so that he won't turn off the radio when he tunes in a symphony orchestra—he is going to appreciate that music. Perhaps he will have a shop in his home where he can do wood carving or some other form of handicraft. In fact, hobby shops may be run by the city.

(Continued to page 148A)



Six-Section Snow Train Rolls on Tires Seven Feet High

BUILT to snake its way across the Arctic, this 274-foot-long Sno-Freighter is probably the world's largest vehicle on rubber tires. It consists of an enclosed power-control cab and five flat cargo cars that can haul 25 tons apiece. In the lead cab car are diesel-electric generating units that deliver driving

power to the 24 wheels, each of which has its own electric motor. The huge Le-Tourneau transporter gets traction in heavy snow with tires that are 88 inches high and 37 inches wide. The metal control car, insulated against severe cold, has sleeping accommodations for a crew of four.



Bike Sounds Like Motorcycle

THE aluminum-colored fiberboard gadget attached to this bicycle looks like a pair of twin cylinders. The gadget's two fingers make contact with the spokes, to produce the motorcycle sound. Bradenton Distributors, Bradenton, Fla., make Bikomotor.



Shell Carries Own Radio Set

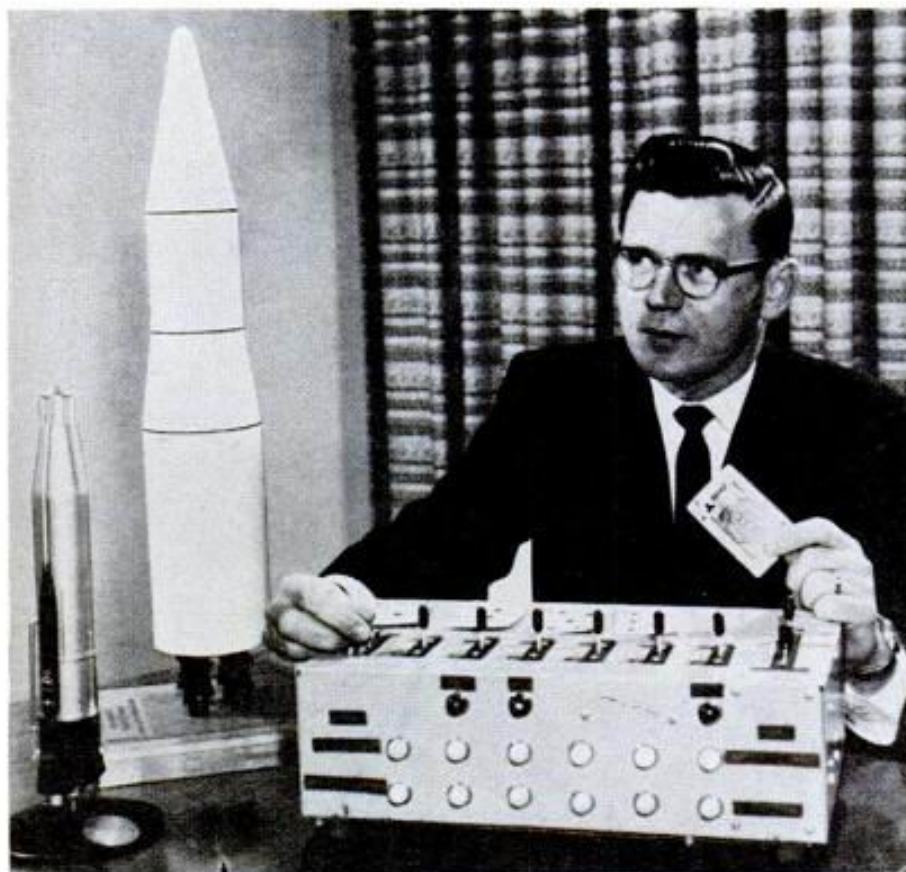
IN THE nose of this 20-mm. shell is a tiny radio transmitter that will withstand acceleration shocks of over 30,000 times the pull of gravity. The Navy uses the device, powered by a mercury battery, to study the spin characteristics of small projectiles.



Cross-country freight train travels on 10-foot tires

A 572-foot-long all-aluminum overland train will deliver 150 tons of supplies to Army outposts over snowfields, desert, or rough ground without benefit of roads or

railway tracks. It's like an earlier version [PS, July '55], but much larger and more powerful. Each of its 54 wheels is propelled by an electric motor in the hub. They draw



Machine learns from its mistakes

The electronic box at left learns lessons like a child. Coded questions are put to it by its teacher, who presses a "punish" lever if it answers incorrectly. After six or eight punishments, the "pupil" learns by trial and error to recognize a playing card (shown being demonstrated by a General Electric official), and from then on it comes up with the right response.

The machine, by its ability to recognize patterns, is expected to help interpret Russian space and missile activity.



juice from gas-turbine generators located in two trailing power cars. The rubber-tired train is driven by a single operator in a control car up front.

The control car has an auxiliary generator, quarters for a crew of six, complete

navigational equipment including radar antenna (visible on top of cab), and is insulated and air-conditioned for tropic heat or arctic cold. The train, built by R. G. LeTourneau, normally consists of 13 cars (only 12 are shown in the photo).

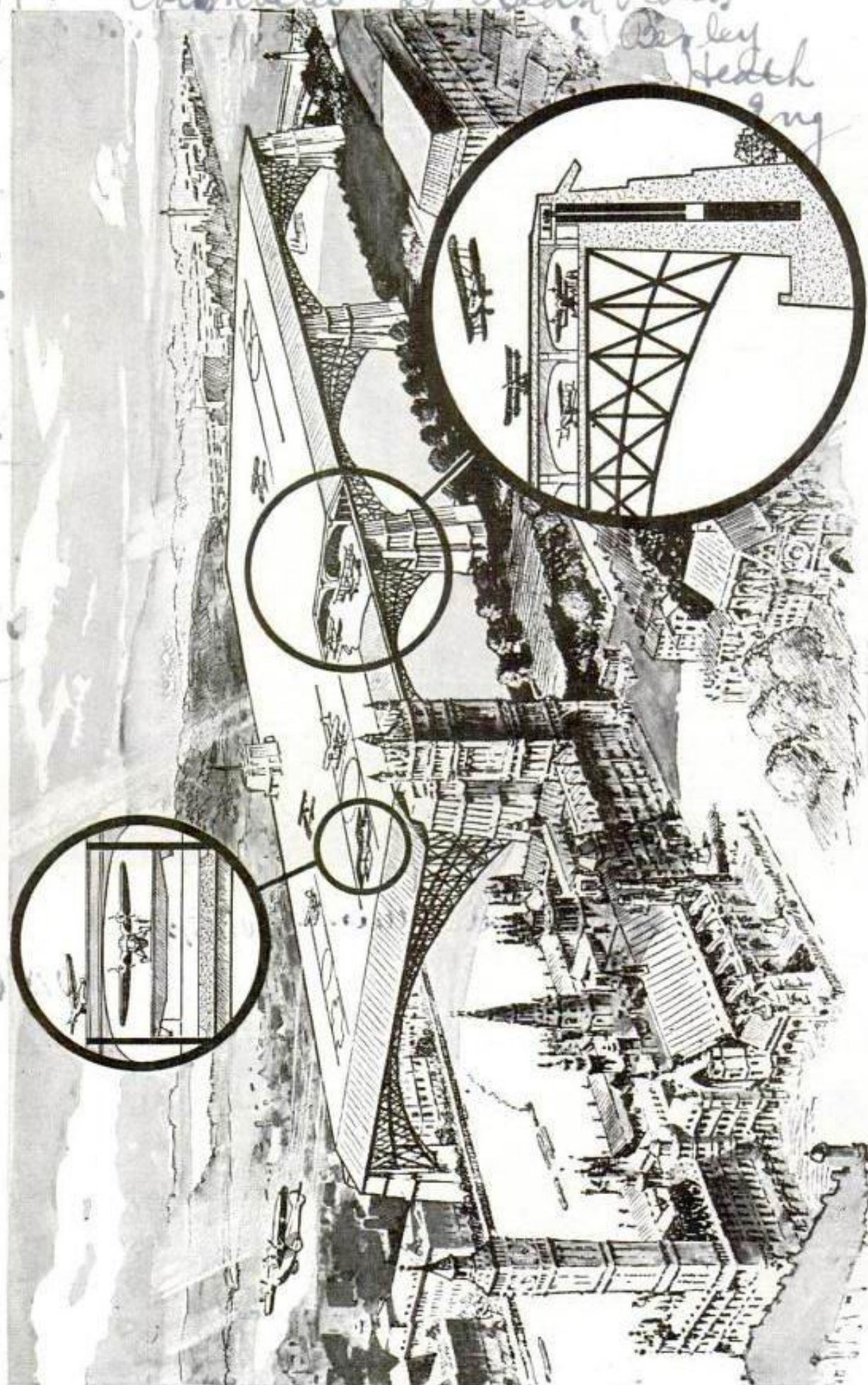


Fishing boat skims shallow water

Three styrofoam floats and a frame of lightweight-aluminum electric conduit take this boat among the reeds and in shallow water where the fish are biting. Heaviest

part is a 37-pound car battery that powers a two-pound electric motor. It turns a hand-made brass propeller for speeds up to seven m.p.h. Steering is by an aluminum rudder. J. A. Wagon, Sherman, Tex., expects to have a modified version in production soon.

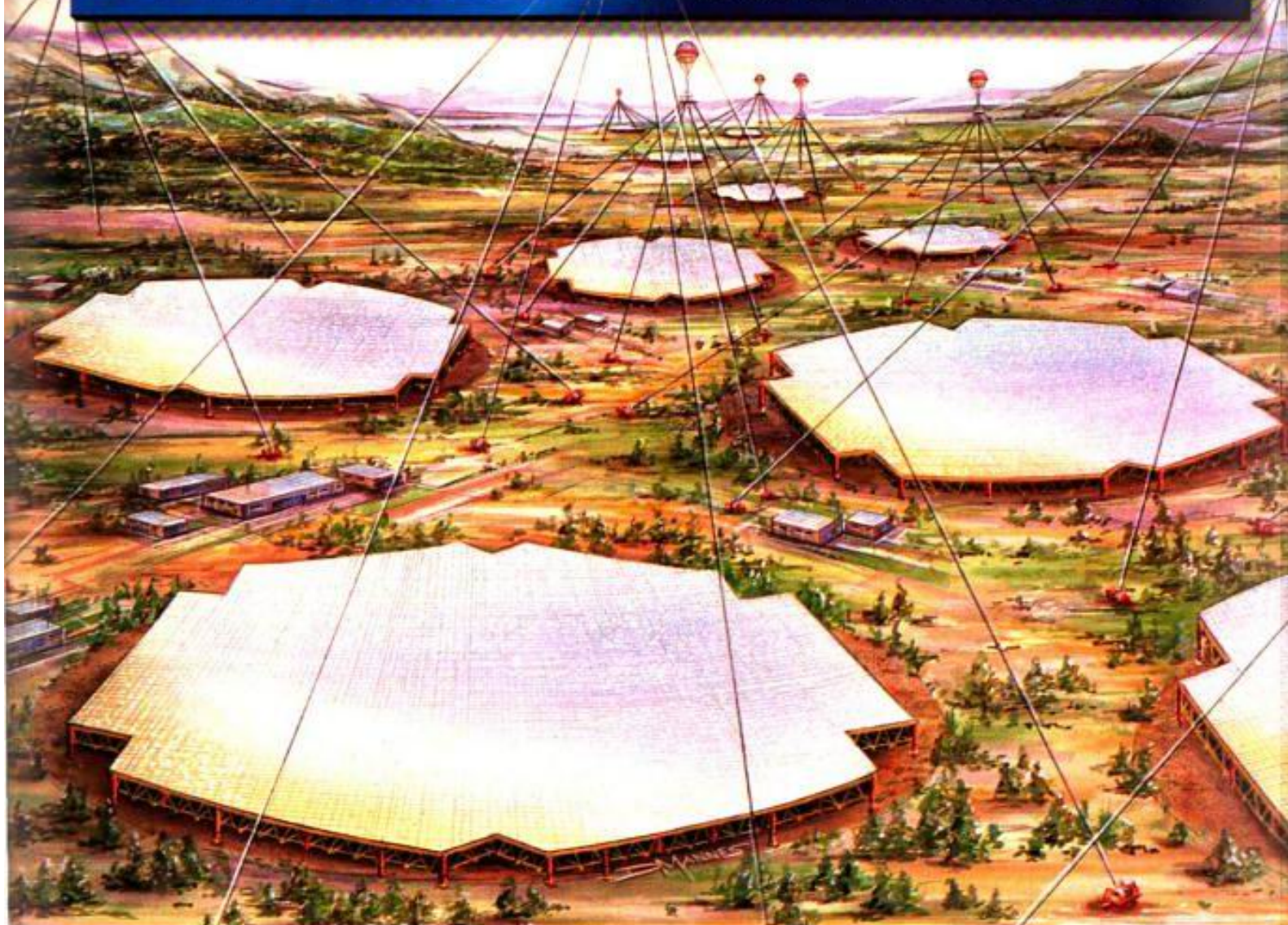
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Courtesy London Evening News
 Sketches of Airdrome Proposed for Construction over the Thames River in London Show How It Would Be Supported by Giant Towers; Cross-Section Views in
 Circles Reveal Plan for Hangar under the Landing Platform; Air Liners Would Be Prepared for Flights to the Continent in This Hangar; Elevators Would Carry
 Passengers to and from the Airdrome

Technology Watch

Aviation • Computers • Energy
Environment • Medicine • Military
Robotics • Space • Transportation



Largest Radio Telescope Ever

A giant telescope will give astronomers their deepest view of space.

Called the Square Kilometer Array (SKA), it will be the world's largest radio telescope. SKA will detect faint energy emissions in the 0.15- to 20-gigahertz range. Its size will make it 100 times more sensitive than today's best radio telescopes. Like existing radio

telescopes, SKA can see through the cosmic dust that obscures the view from conventional

optical telescopes.

One design concept, shown here, would gather weak signals with a bank

of steerable collection arrays and concentrate them on receivers held aloft by balloons. Computer controls would link individual arrays, so the system could look at 100 fields of view simultaneously.

"SKA's superior resolving power and image quality will be crucial to studying the formation and early history of stars, galaxies and quasars," says a spokesman for the 10-nation SKA Consortium.

A final telescope design and location will be selected in 2005. Construction could start in 2010.



November Highlights

Oshkosh Action—Builders fly their own at the annual experimental aircraft show.

■ **Stowing Steam**—U.S. Navy begins conversion to an all-electric fleet of fighting ships.

■ **California Dreaming**—Disney looks to its roots for inspiration for its latest theme park.

Editor: Jim Wilson
Reporters: Carol Carder, Stefano
Coledan, Mike Filon, Leslie Hicks.

JULY

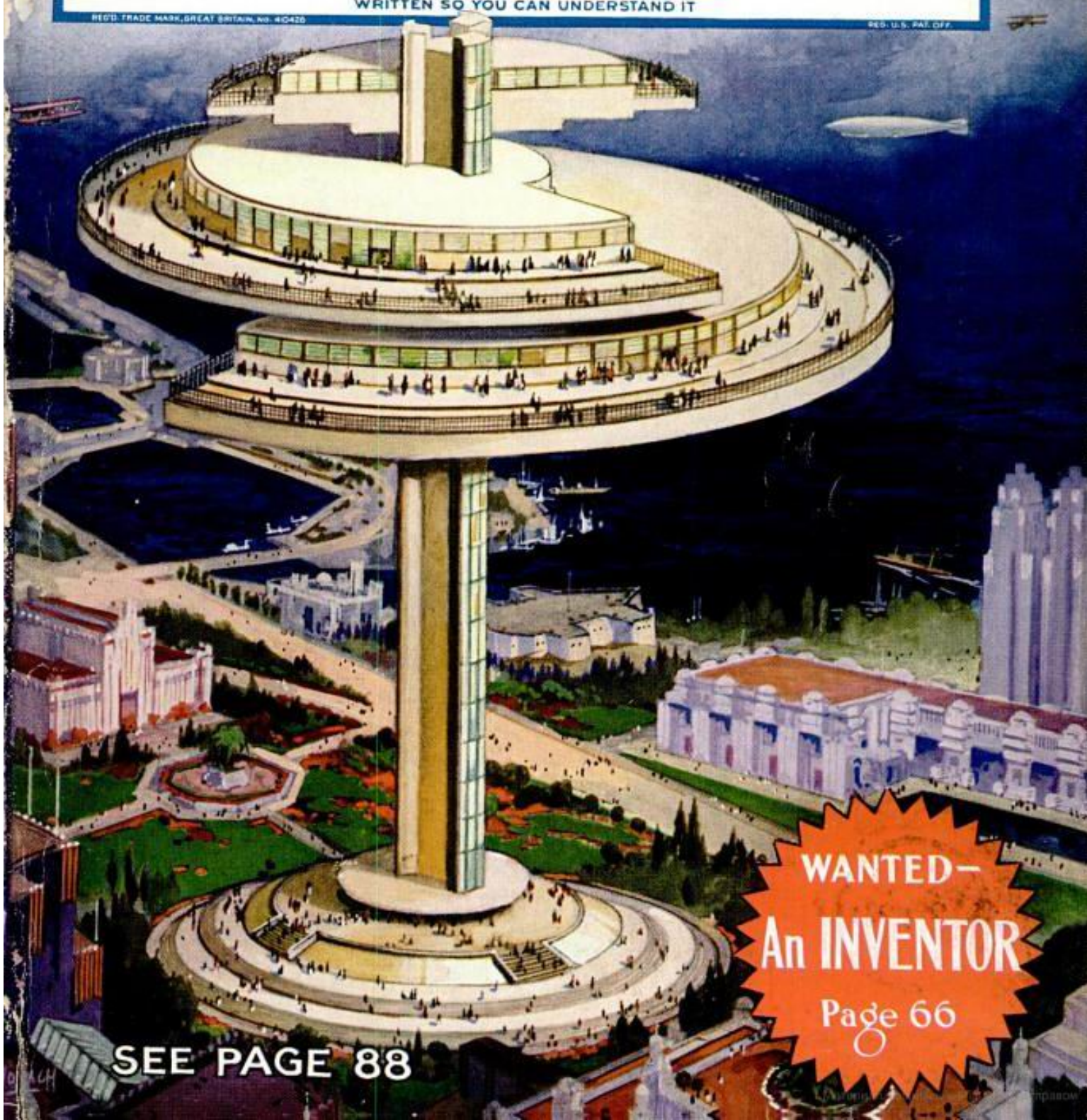
N.S.E.
25 CENTS

POPULAR MECHANICS MAGAZINE

WRITTEN SO YOU CAN UNDERSTAND IT

REGD. TRADE MARK, GREAT BRITAIN, NO. 40426

REG. U.S. PAT. OFF.



WANTED—
An INVENTOR

Page 66

SEE PAGE 88

Designed by Norman Bel

88

Ladd's POPULAR MECHANICS

682



Design of Modernistic Restaurant, Built atop a Column Which Revolves with Diners or Sight-Seers

RESTAURANT BUILT ON COLUMN REVOLVES WITH DINERS

Among the modernistic building designs prepared by architects for submission to the Chicago World's Fair Centennial committee is that of a revolving restaurant mounted on a huge column. The structure is spiral in effect with promenades and space for indoor and outdoor dining rooms. Both building and column revolve once each half hour, thus affording an opportunity for sight-seeing while dining or strolling on the platforms. The model provides space inside the column for elevators, while at the base are foyers and a space for parking of automobiles.

EARTH IS AHEAD OF SCHEDULE IN ITS ROTATION

Through observations on eight different bodies in the solar system, scientists have obtained proof that the earth is ahead of schedule in its rotation, and hence is not quite reliable as a timepiece. For some years it has been suspected that the earth is not exactly regular in this respect, and at one time scientists attributed this to a shrinkage of its diameter. Dr. Ernest M. Brown, Yale mathematician, however, says

observations over many years indicate some sort of order in this irregularity. At present the earth is running ahead a fraction of a second a day. It appears to lag for a certain number of years, then to speed up for a like period. There were changes in its rate of rotation in 1897 and 1917, and the rate probably will change again in the next few years. At first the changes were attributed to the moon, but observations of the sun showed the same variations, indicating that the earth, rather than the moon, was in error, and these were borne out by studying other planets, so that now the changes in speed of rotation are accepted as fact.

LIGHT SCHOOL IN SKYSCRAPER

680 AIDS HOME MAKERS

Better ways to illuminate homes, offices, factories, airports and other places are shown in a school established by the Chicago Lighting Institute on the thirty-sixth and thirty-seventh floors of the Civic Opera building. To demonstrate proper home lighting, a six-room bungalow has been installed, fitted with the newest ideas in fixtures and displaying methods of direct and indirect lighting. How colored patterns of light are projected on the walls and ceilings is illustrated. A special feature of the institute is its two-story

28 N. Wacker Drive.

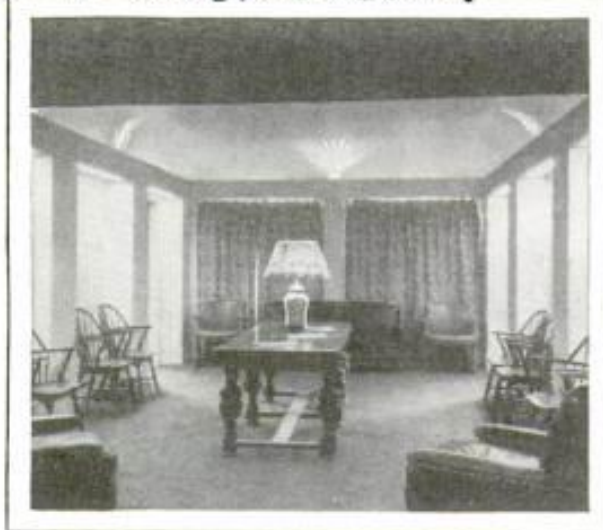
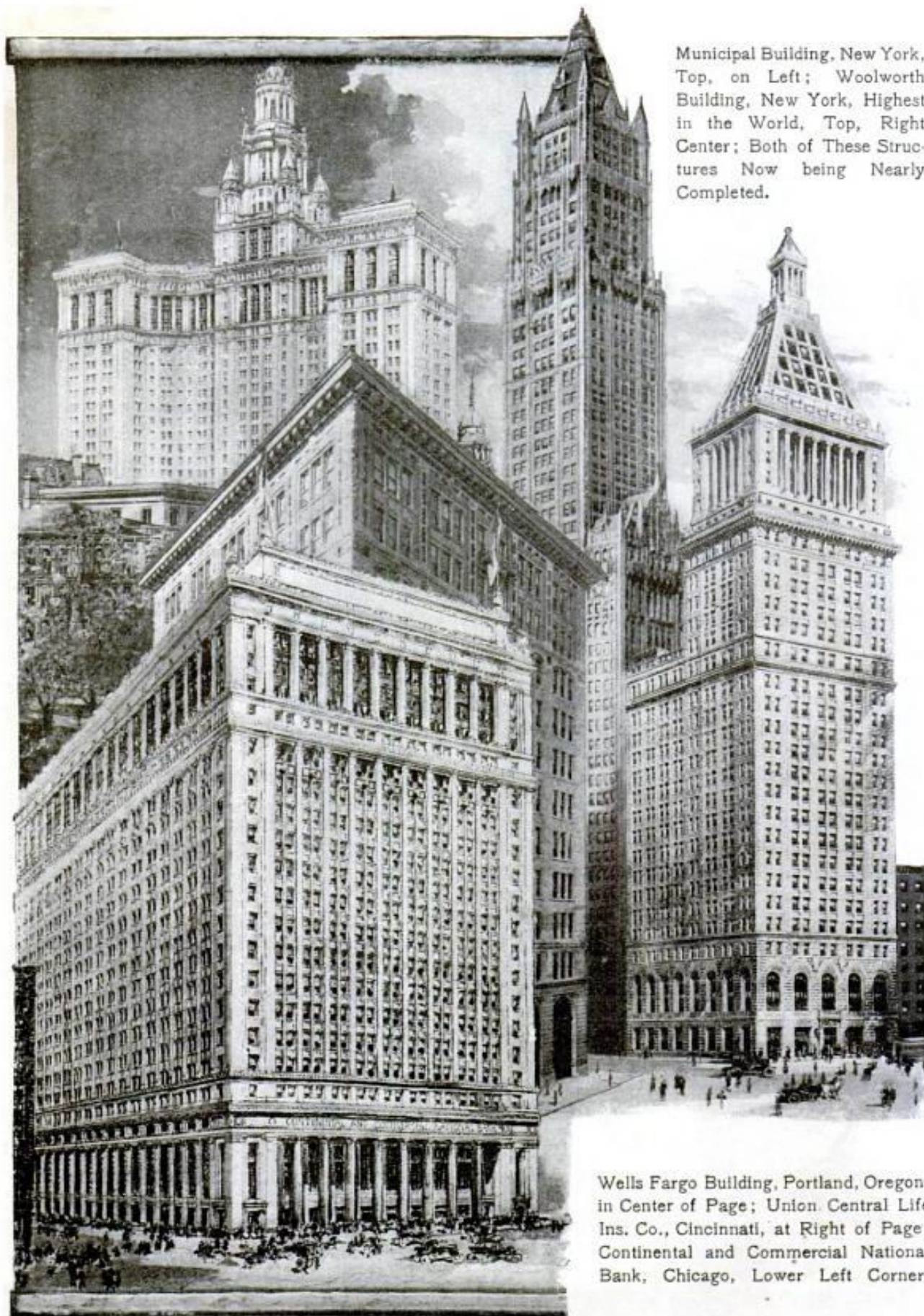


Exhibit Room in the Chicago Lighting Institute, Showing Installation of Ceiling and Wall Illumination

auditorium, seating 225 persons. The stage is set with a replica of a modern city, which is illuminated by various methods of flood and special lighting.

Chicago Tribune 4/27/30



Municipal Building, New York, Top, on Left; Woolworth Building, New York, Highest in the World, Top, Right Center; Both of These Structures Now being Nearly Completed.

Wells Fargo Building, Portland, Oregon, in Center of Page; Union Central Life Ins. Co., Cincinnati, at Right of Page; Continental and Commercial National Bank, Chicago, Lower Left Corner.

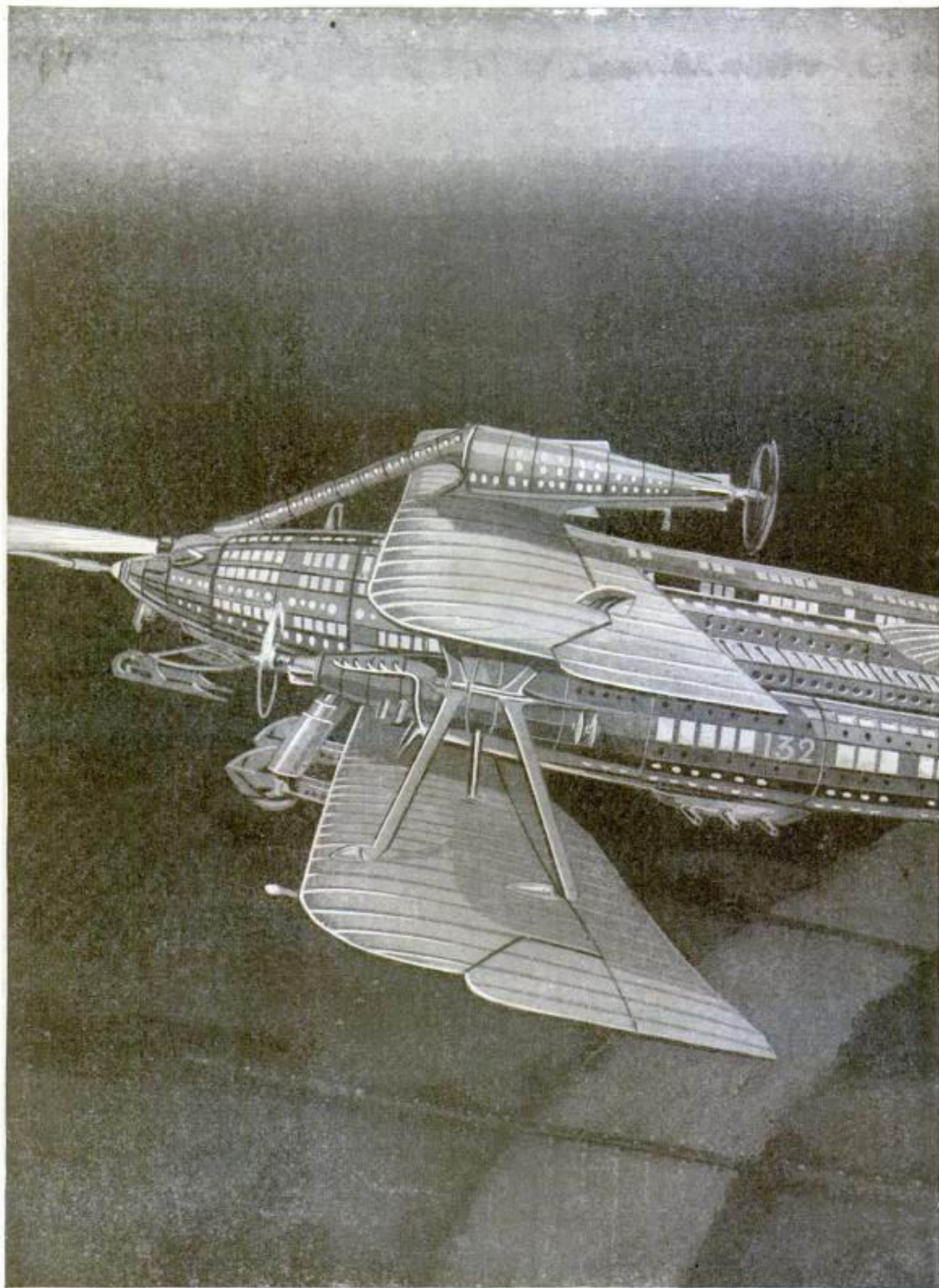
L. C. Smith Building, Seattle,
Tower Building at Top of
Page; Whitney National Bank
Building, New Orleans, Top at
Right Center; Hoge Building,
Seattle, Upper of Two Build-
ings on Right.



Maryland Casualty Company Building,
Baltimore, on Left; Front View of
Whitney National Bank, New Orleans,
Lower Center; Woodmen of the World
Building, Omaha, Lower Right Corner.

501

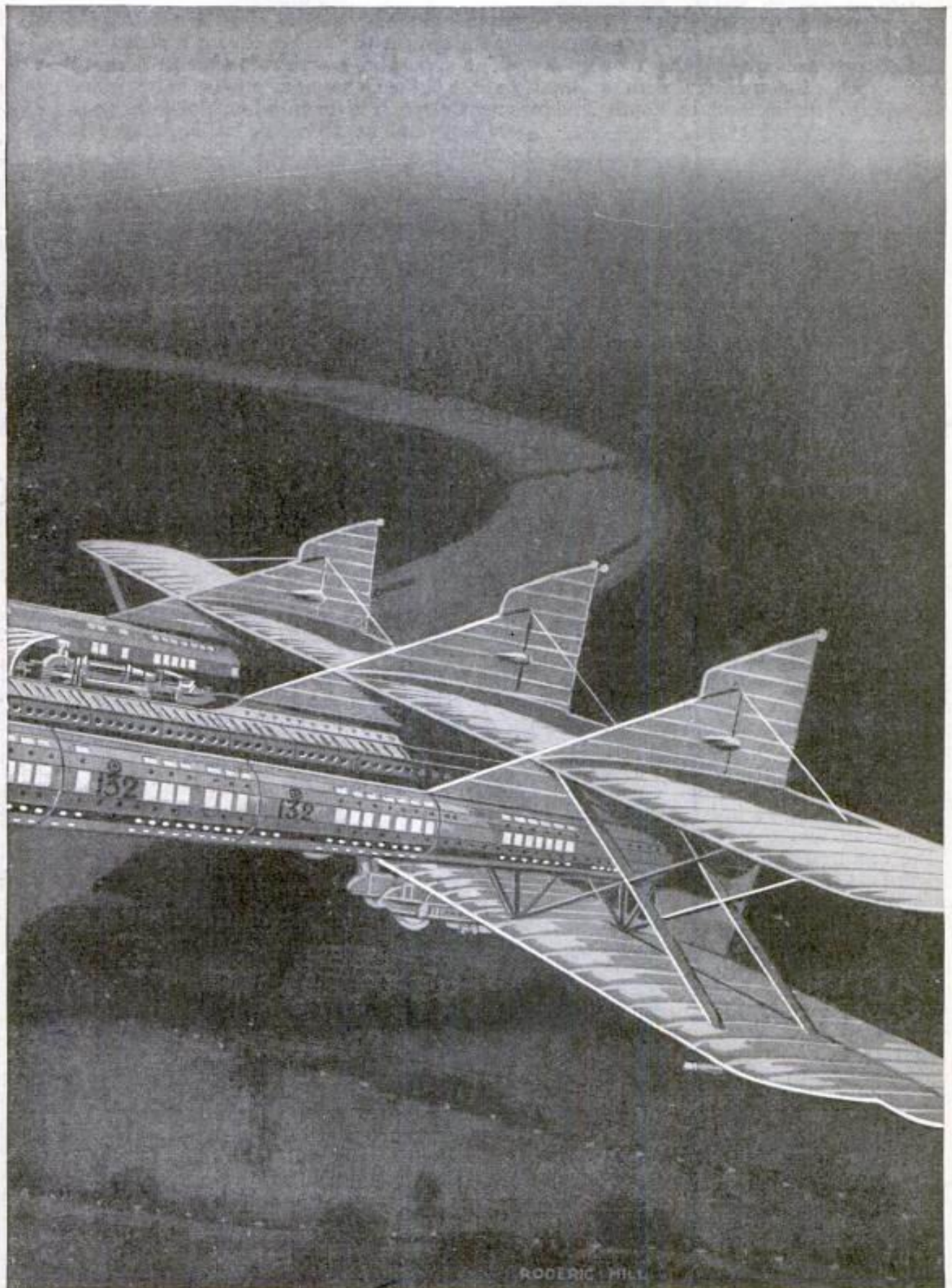
The Great Air Liner of the Future



Con. leay

With Space for Hundreds of Passengers, the Air Liner, It Is Predicted, Will Be Built Entirely of Metal and All Parts Will Be Inclosed Including the Motors

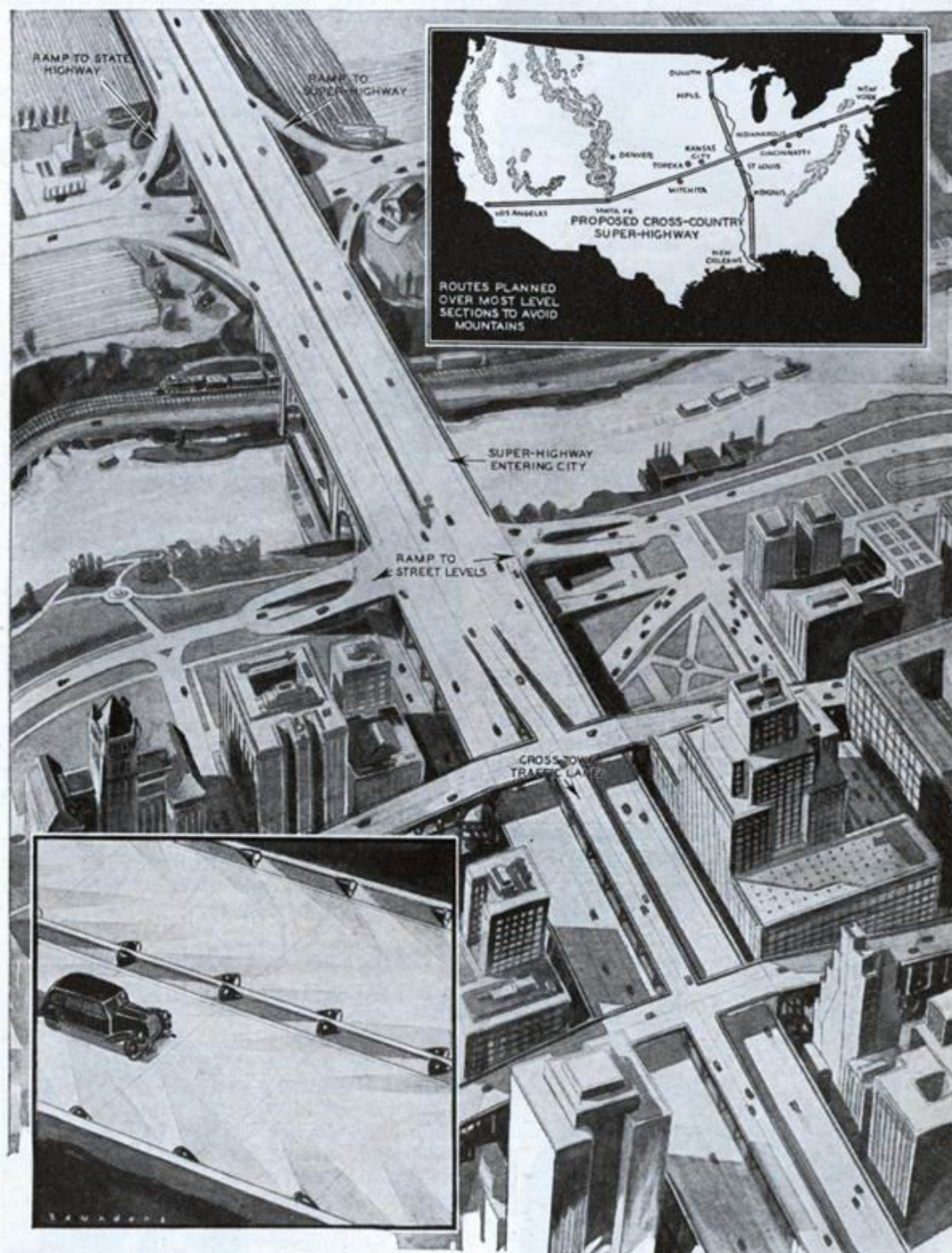
as Described to British Association



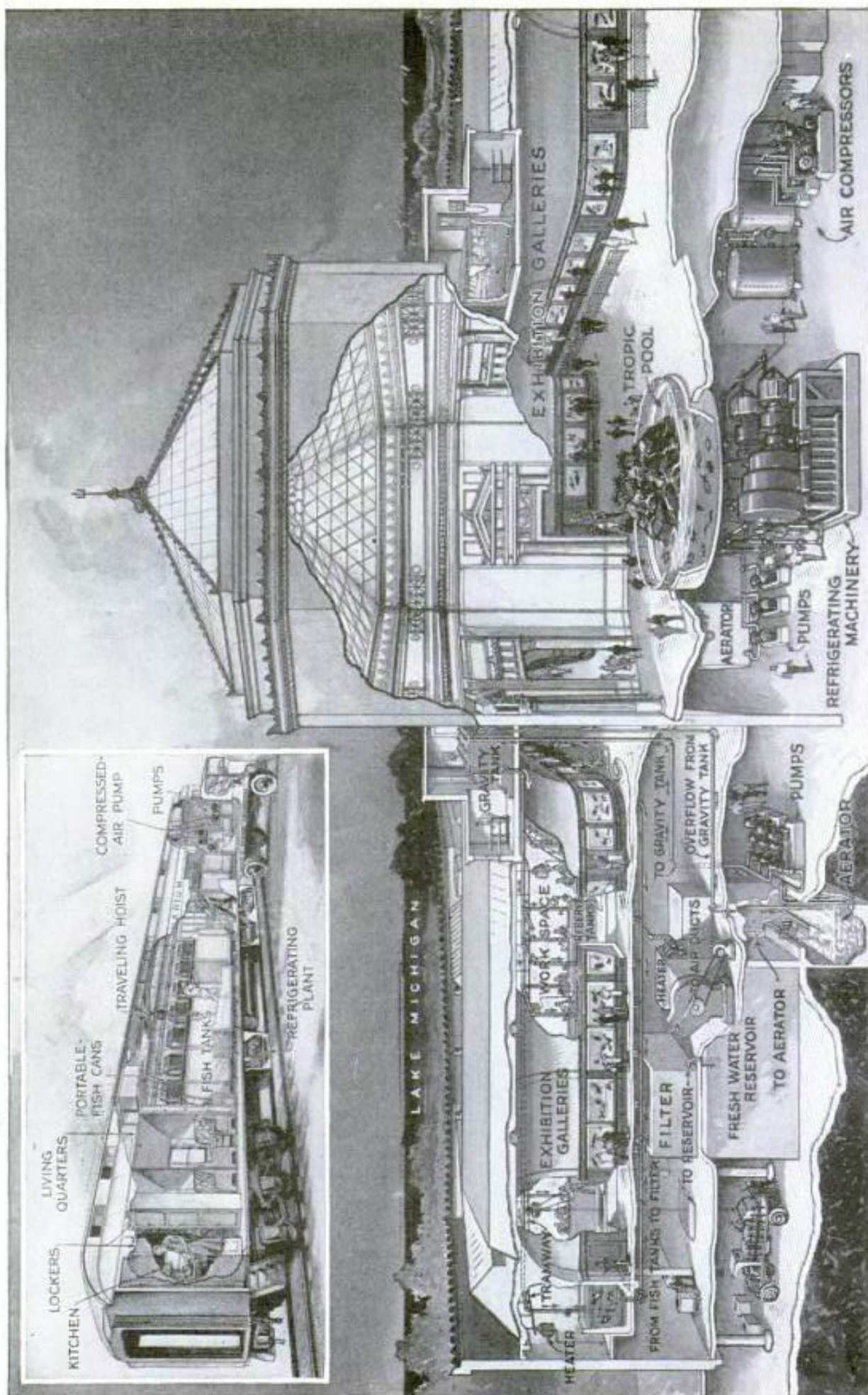
The Sphere

Sept. 19, 1925
An Artist's Vision of the Great Transatlantic Air Liners of the Future Which Were Described by Speakers before a Recent Meeting of the British Association

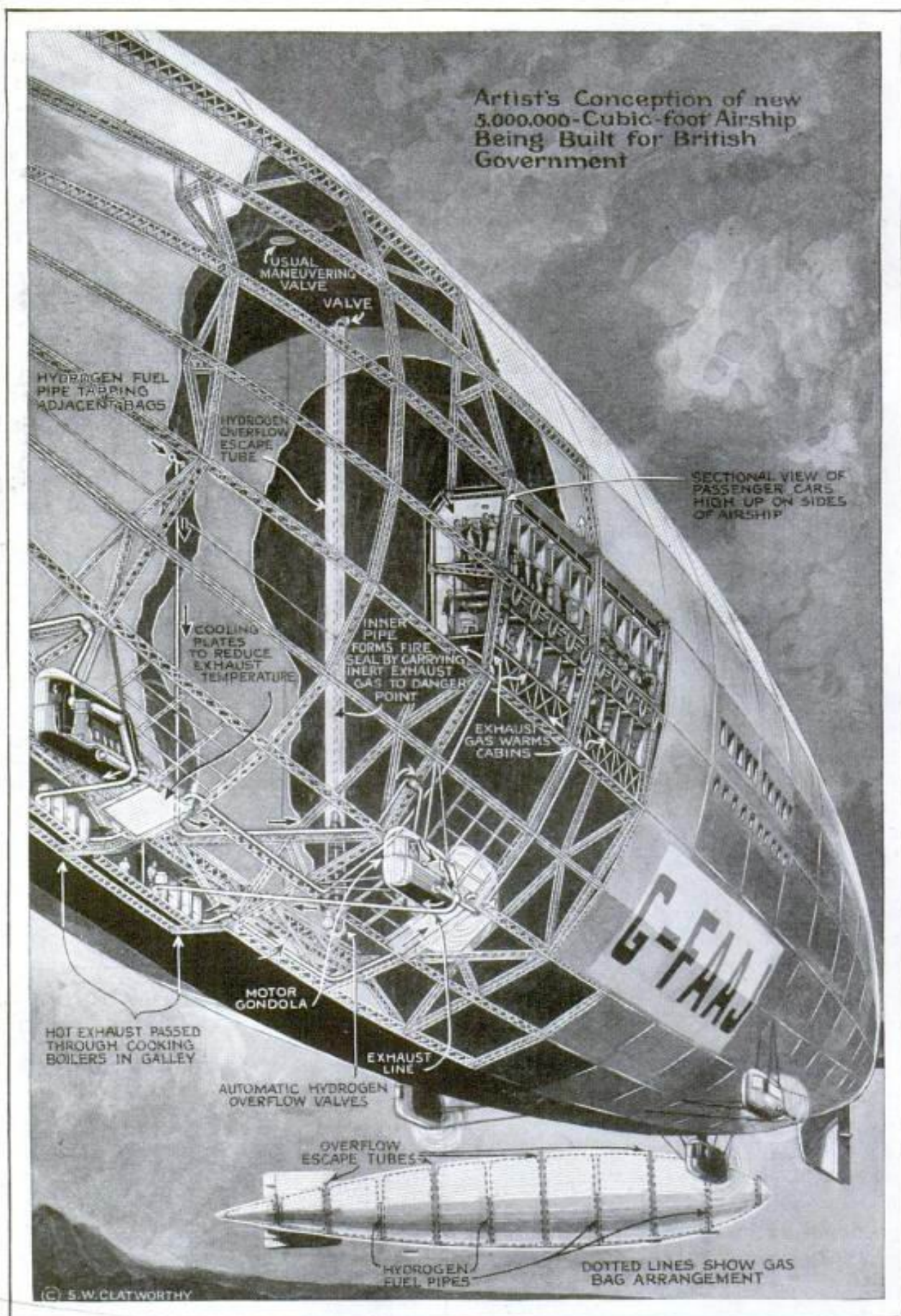
Cross U. S. In 48 Hours On Proposed Road



An artist's drawing of the proposed coast-to-coast super highway on which automobiles may travel at speeds of 100 miles an hour, making the trip between New York and California in forty-eight hours. Road builders are now working on plans for a four-lane highway with all grade crossings eliminated. The super roadway will be elevated through towns with ramps furnishing access to the main road through a central lane. Night travel is expected to be fully as safe at high speeds as day touring. Parapet walls two feet in height and made of opal glass bricks are intended to flank the black-surfaced roadway. Imbedded in the walls and spaced about twenty feet apart, as shown in insert, the engineers intend to put lights whose hoods will direct the light on the pavement below the eye level of the automobile driver.

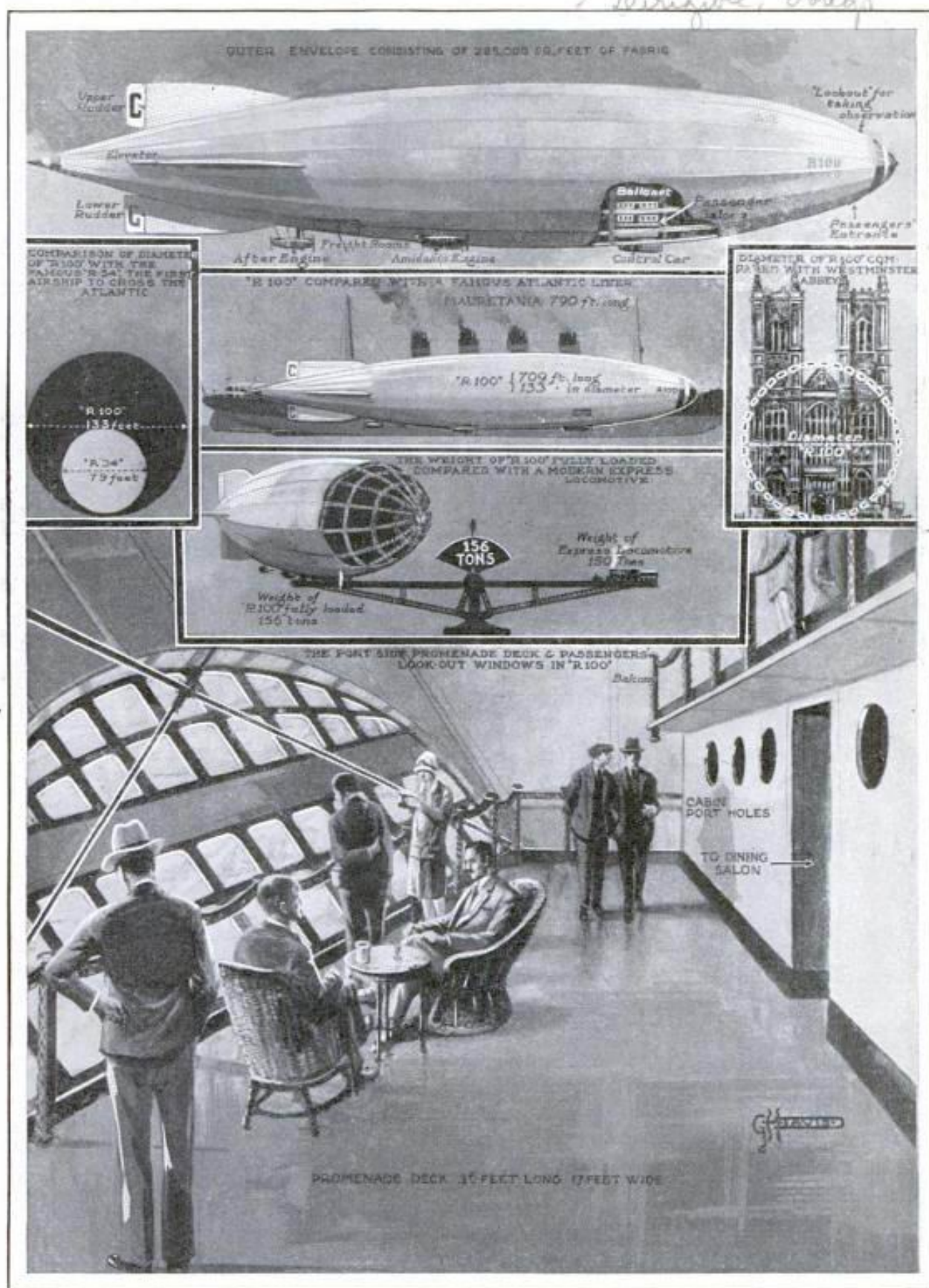


Artist's Drawing of the Shedd Aquarium and the Special Pullman Car Built to Transport Fish; It Is an Aquarium on Wheels; the Large Sketch Shows How Boxes Are Unloaded from the Motor Trucks on Electric Hoist and Placed Directly in Tanks; General Plan of Water Circulation Is Also Illustrated



England Is Seeking a Way to Make Hydrogen Gas Safe for Airships by Surrounding It with a Layer of Burnt-Out and Inert Exhaust Gases from the Motors of the Ship—See Page 204

TRANSATLANTIC FLYING HOTEL NEAR COMPLETION

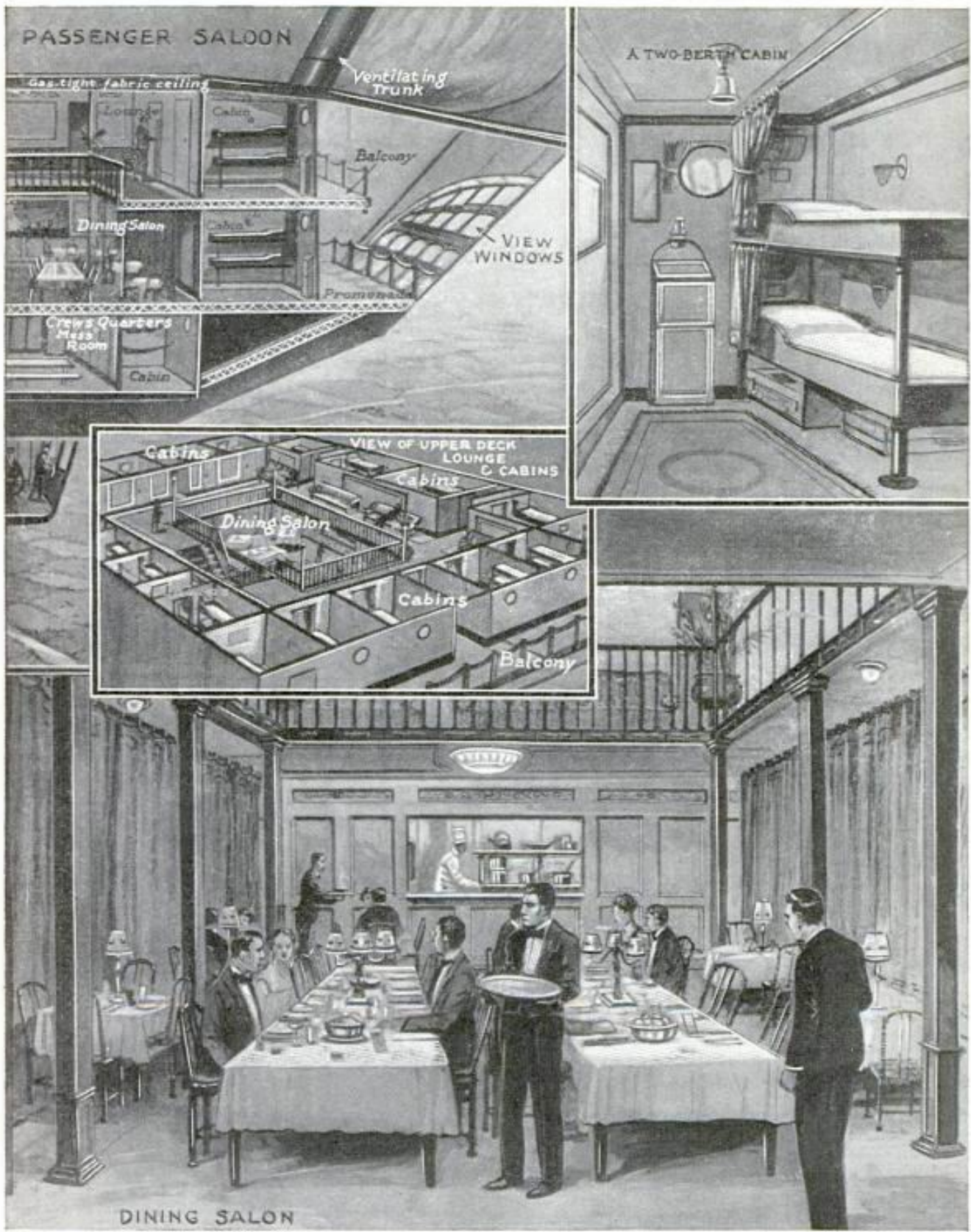


© in the United States

Nearly as Long as the Famous Liner "Mauretania," the "R-100," a Flying Hotel with Accommodations for One Hundred Passengers, Will Take the Air in England Some Time This Spring



IN OCEAN TRAVEL WHEN IT COMES TO U. S. SOON

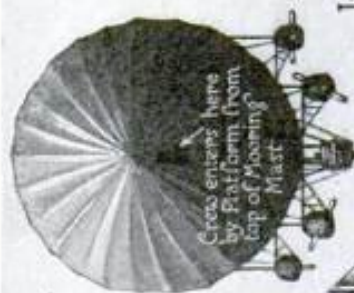


the United States

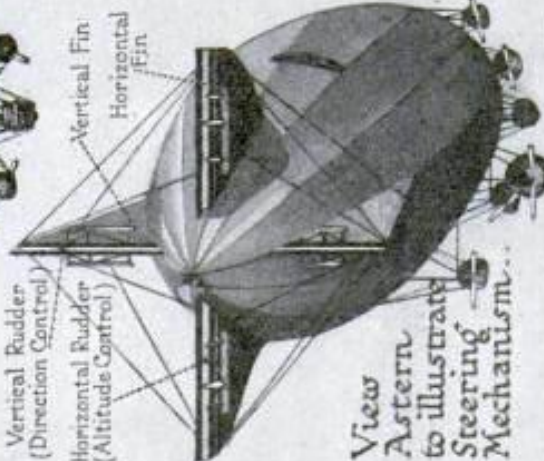
Six Engines of 650 Horsepower Each Will Drive the Ship, While the Three-Story Hotel Section, So Light It Weighs But Twenty Tons Loaded, Has All the Comforts of Home

Head-on View...

The Cars are arranged thus to avoid the Air Wash between the Propellers



Vertical Rudder (Direction Control)
Horizontal Rudder (Altitude Control)



View Astern to illustrate Steering Mechanism

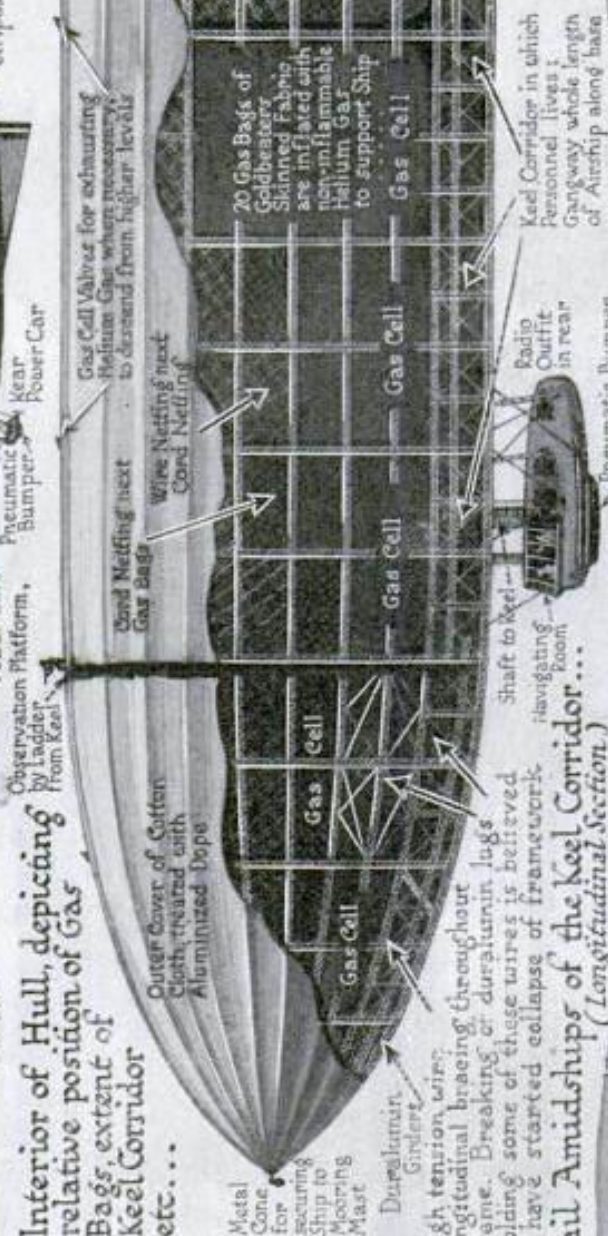
Each Power Car has a 300 H.P. Motor

General View of "Shenandoah" showing Arrangement of the Six Cars...

Total Length of "Shenandoah"... 682 ft.
Diameter at Mid-section... 78 ft. 9 in.
Total Weight... 41 tons
Normal Speed... 60 m.p.h.



Interior of Hull, depicting relative position of Gas Bags, extent of Keel Corridor etc...



Detail Amidships of the Keel Corridor... (Longitudinal Section)



Food Locker, Keel is open, no separate compartment with except 140 Fuel Tanks, 113 gals.

Structural Details of the First American-Built Dirigible; the Steel-Wire Bracing, Shown in the Sectional View, Gave Way When the Storm Stresses Ripped the Fastening Lugs from the Rivets and Precipitated the Collapse of the Frame by Permitting the Ribs and Girders to Fold Up

366. *Cmt. S. W. Clatworthy, Esq. 18.*
Shakespeare Road, Herne Hill
London. S. E. 24. England
at Ideal Homes Exhibition
Home, Sweet Home of the Future

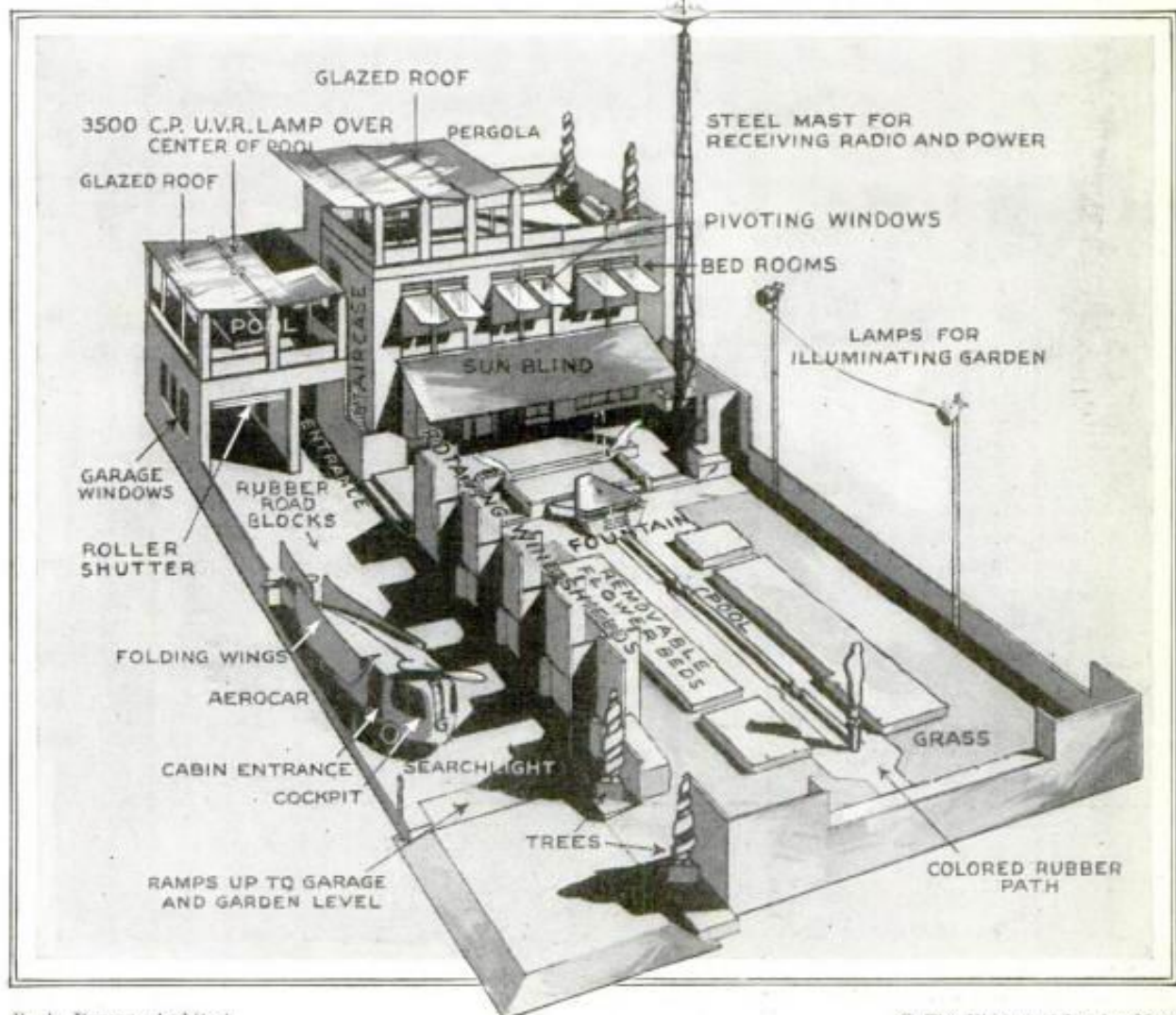
Television, Artificial Sunlight, Pneumatic Furniture, Metal Fittings and Unique Materials Combined in Architect's Vision

THE home of the future, as an architect envisages it seventy years from now—about the year 2000—was exhibited, full size, in London recently as a sunbeam house in a land of perpetual sunshine. "Vitaglass," to admit the sun's ultraviolet rays in fair weather, and artificial sunlight for cloudy days and night use, provided a permanent summer-day effect.

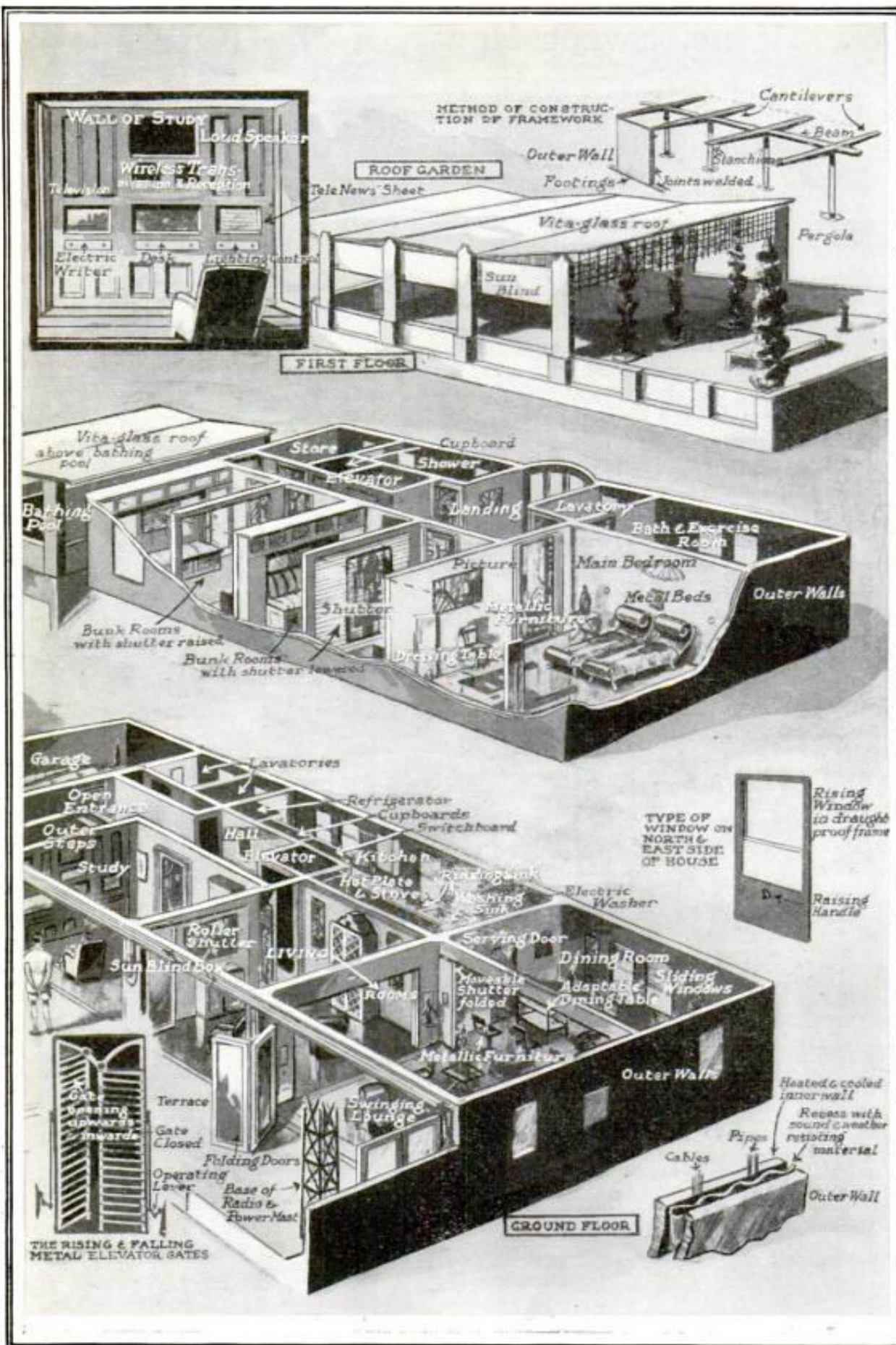
Convertible metal and pneumatic furniture, "bunk" rooms instead of bedrooms, laid out somewhat like steamer cabins, movable walls, metal furniture, a profusion of unusual electrical apparatus, a garage for a combination airplane-automobile, with folding wings, and, on the ga-

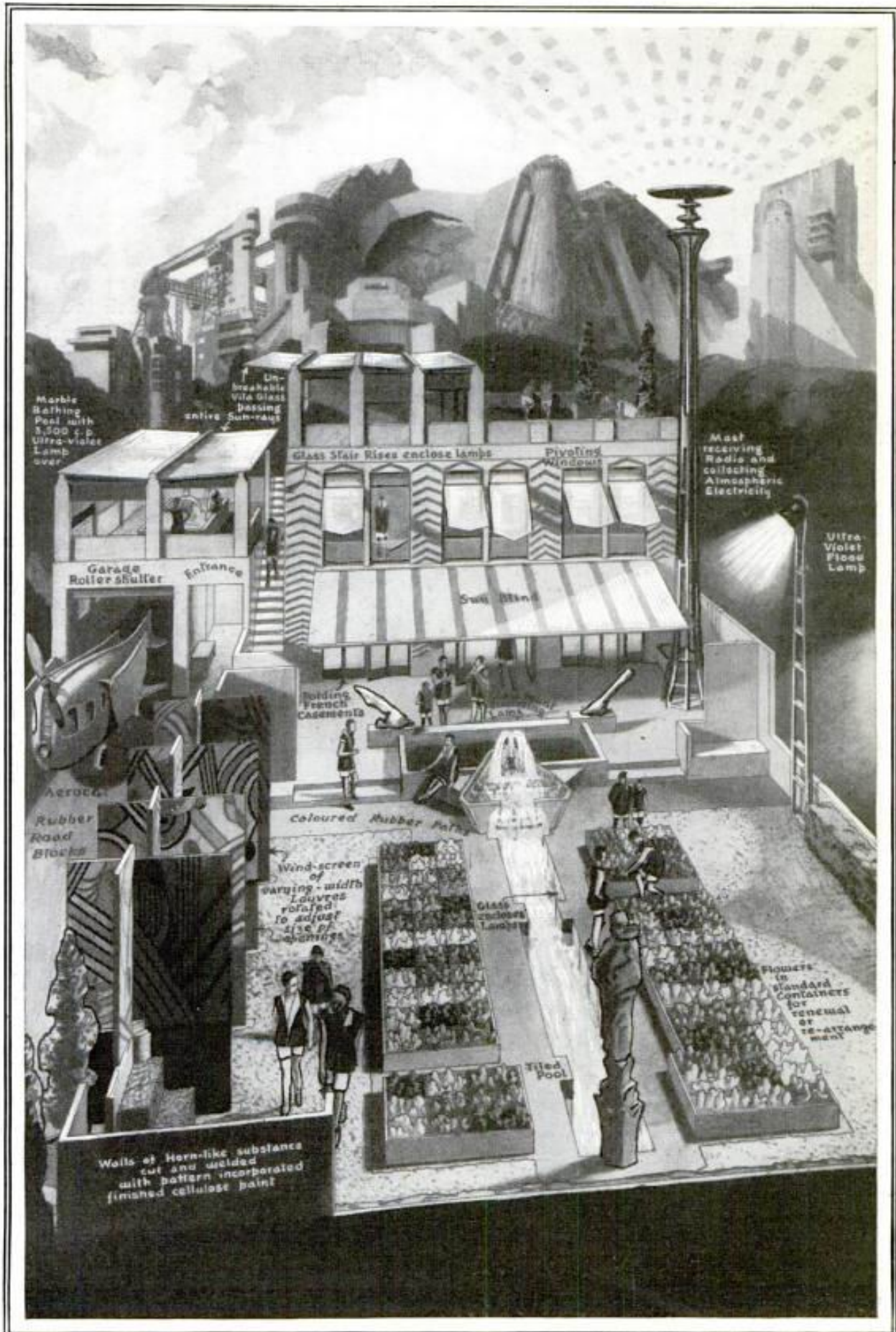
rage roof, a second-story swimming pool, gardens fitted with plants in movable containers so that new floral effects could be worked out at will, rubber-tile garden paths, wireless power and program reception masts, and banks of ultraviolet floodlights, were among the features.

The house, designed by R. A. Duncan, was severely plain, but its simplicity was relieved by futuristic plants and trees, formed of angular boards, painted in something resembling war-time camouflage designs, and a system of movable wooden wind screens along the garden wall to shut off or admit the breezes to any degree desired.



R. A. Duncan, Architect





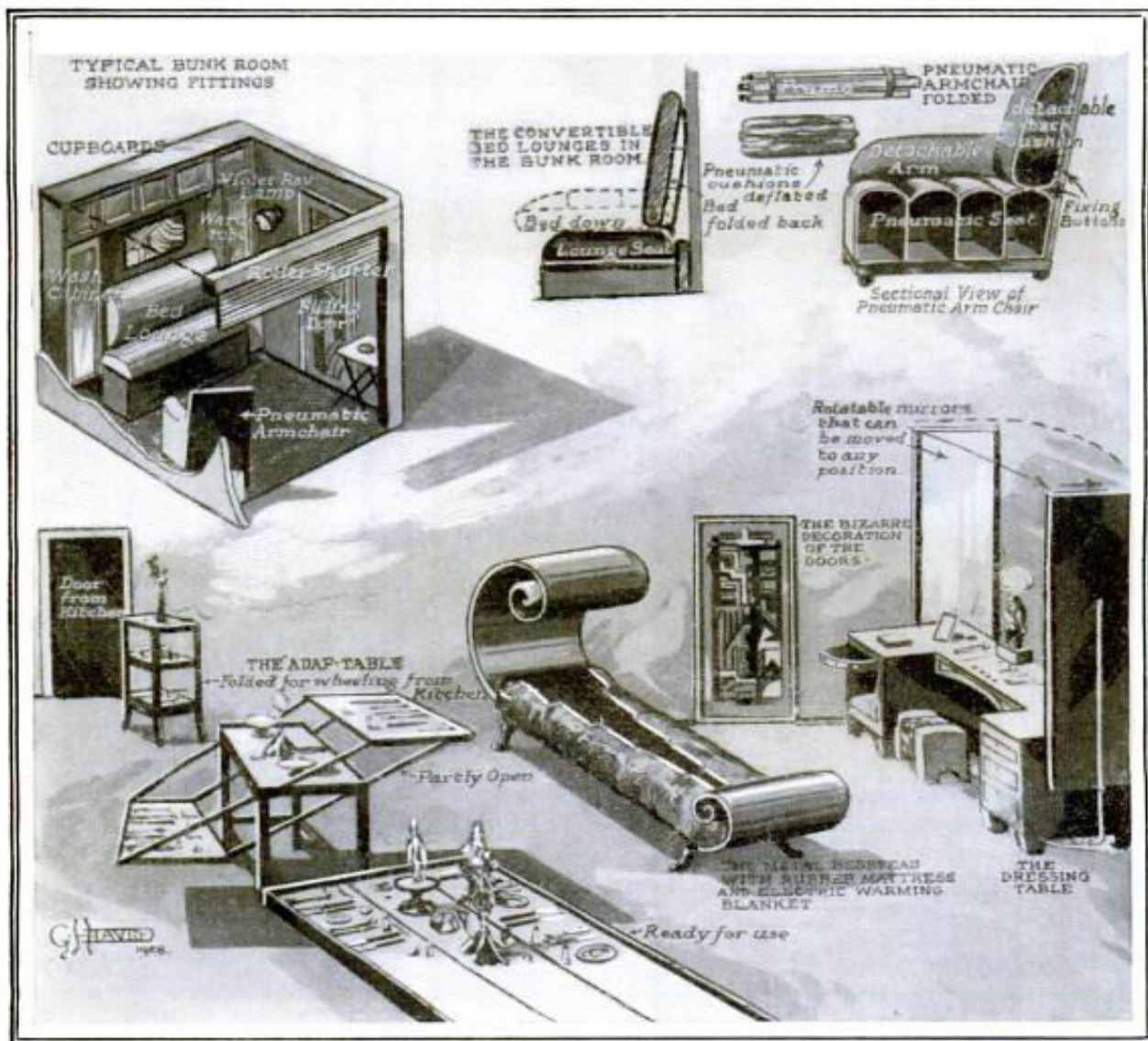
Electricity was predominant everywhere. A sunken garden pool and the fountain feeding it were illuminated by night from under-water lights in many colors. The queer metal beds with pneumatic mattresses were equipped with electric blankets for warmth. The study wall was lined on one side with built-in radio and loud speakers, a built-in television set to see the day's events and a built-in tele-newspaper for visible radio projection of the day's news. An electric writer, to transmit by radio similar written messages, and an elaborate lighting-control panel also were included.

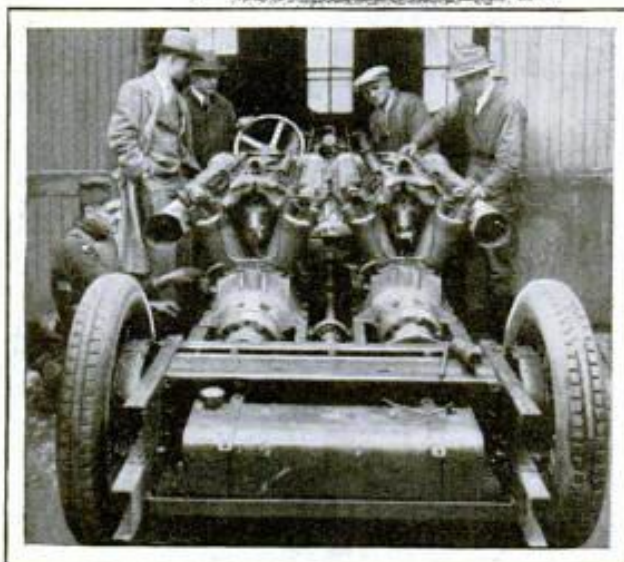
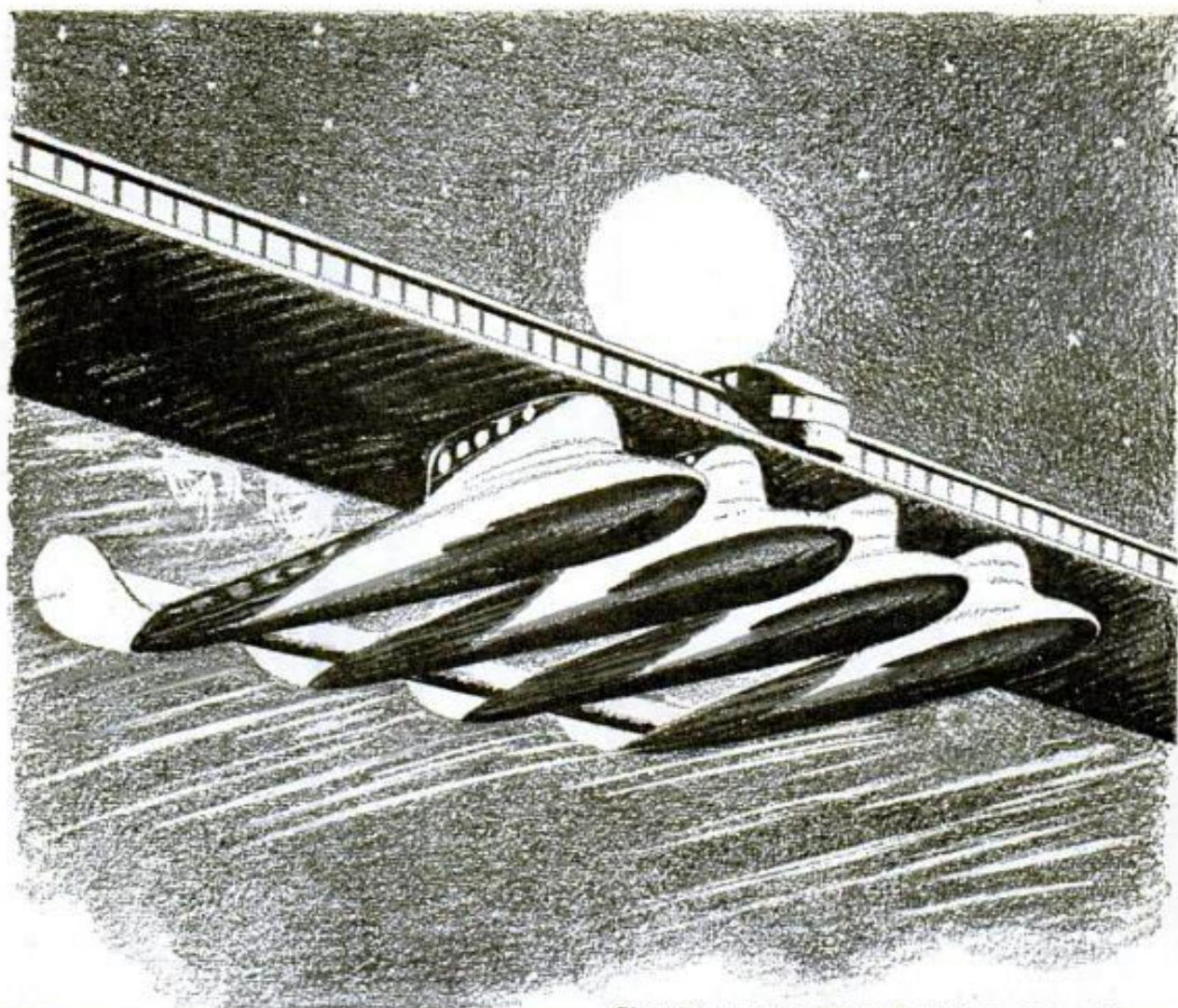
Pneumatic armchairs, with enormous inflated cushions built up in sections, were placed in the bed and living rooms. The chairs can be deflated and folded up into a small space when not needed.

Besides the main bedroom, with twin

beds and metal furniture, there was a whole series of individual bunk rooms. The walls between them could be rolled up, like awnings, to throw two rooms together as one. Pivoting windows, sun blinds, a roof garden inclosed in vitaglass, and walls, specially insulated and provided with an inner surface that can be either heated or cooled, were other features. The wall was an unusual three-ply construction, an outer wall, an insulated space, which also contained all pipes and electric wires, and the inner wall, which took the place of radiators for winter heating, and provided a cooling system for summer.

Much of the furniture was unusual. The dining-room table was built in three sections, the two side parts being interconnected through a system of levers so that the table could be folded up as a three-story tea cart and wheeled in from





Giant Transatlantic Flying Boat Proposed by a German Inventor, and, Left, the Three-Thousand-Horsepower Triple-Engine Car That Set a World's Speed Record at Daytona Beach

behind the wing. The propellers are to be of the relatively slow, and highly efficient, four-bladed type.

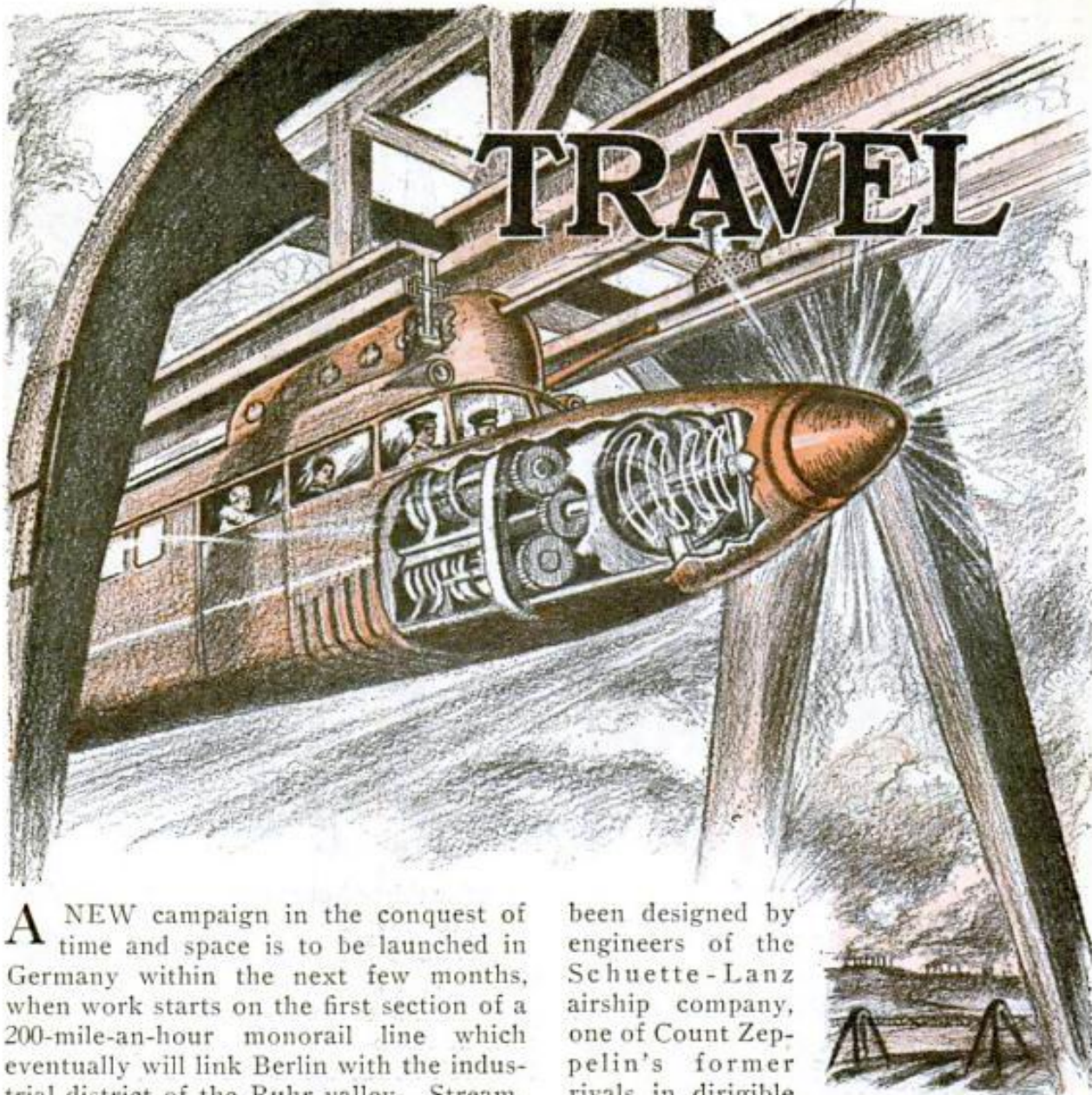
The fuselage, which will contain the passenger compartments, is modeled along the lines of a boat, even to the flaring cruiser bow, and, when at rest on

the sea, will be equipped with demountable boat railings. The twelve 500-horsepower engines will make it the most powerful airplane ever built. Nine men will be carried in the crew—two pilots, a navigator, two wireless operators, two mechanics and two stewards.

Another German company is experimenting with a high-speed surface liner, which, instead of being pushed through the water by a propeller, will be pulled along by suction blades, drawing water into the hull and expelling it through openings farther aft. The experimental model provides four suction turbines, two on either side just aft of the bow, and two well back toward the stern. The hull itself would be of the "teardrop" type—the most efficient streamlined shape—fairly blunt forward and "finned down" to a point at the stern, and all the super-

Worked out by French engineers, Hirschauer and Salom.

600. Col. George F. Paul,
537 S Dearborn
Chicago



A NEW campaign in the conquest of time and space is to be launched in Germany within the next few months, when work starts on the first section of a 200-mile-an-hour monorail line which eventually will link Berlin with the industrial district of the Ruhr valley. Streamlined torpedo-shaped cars, driven by airship propellers at either end, are to be hung on ball-bearing rollers from an overhead track.

Monorail lines are not new in Germany, for several are already in operation. The novelty of the new project is the great speed expected from the use of air propellers instead of the usual geared driving wheels.

Electric motors are to turn the propellers, getting their energy from a trolley rail, so that no fuel will be carried. Two experimental sections have been planned, one from Berlin to Halle and the other from Cologne to Dusseldorf, and work on one or the other is planned to start before the end of the year. The aerial cars have

been designed by engineers of the Schuette-Lanz airship company, one of Count Zeppelin's former rivals in dirigible building. The projected speed—200 miles an hour—is practically double that of passenger-carrying airplanes, nearly three times the most efficient cruising speed of Zeppelin airships, and almost four times as fast as the railway schedule for the same distance. In fact, not many racing planes, and only a very few special racing automobiles have ever attained it. When Ray Keech, driving the White triplex car, powered with three Liberty engines, recently set a new world's record of 207.5526 miles an hour on the Daytona sands, only two other drivers had officially passed the 200-mile mark—Capt. Malcolm Campbell and Maj. Segrave. Keech made 213.90374 miles an hour over the measured-mile course, trav-



of the FUTURE

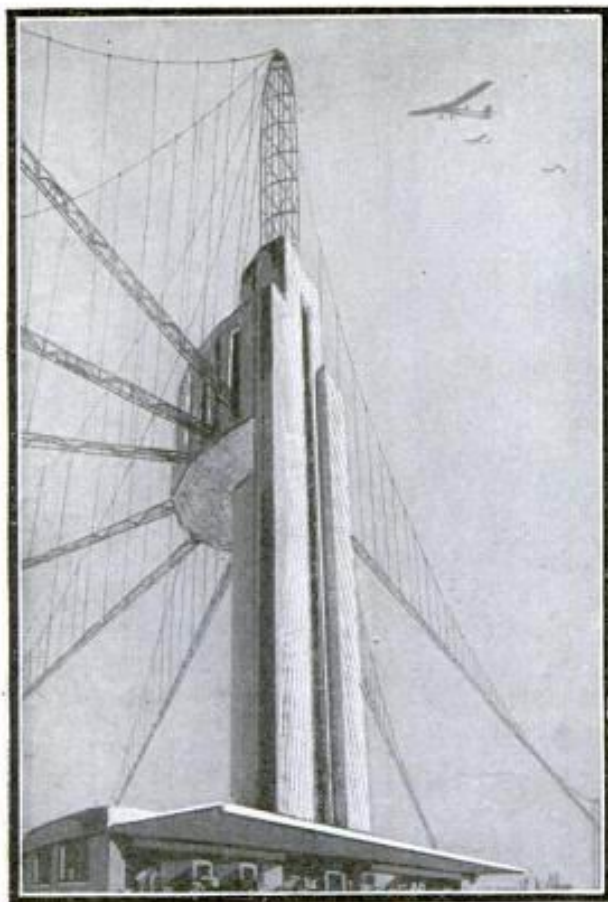
Preliminary Sketches of Germany's New Monorail, with Torpedo-Shaped Cars to Be Drawn by Air Propellers

eling with the wind, and 201.56774 against a thirty-mile-an-hour breeze.

The suspended-monorail idea has always interested high-speed railway inventors because it eliminates the difficulty of building a roadbed and track capable of standing the constant punishment of fast traffic. A California inventor recently proposed an elevated monorail line for San Francisco to carry cross-town traffic at sixty miles an hour or faster. His plan contemplates long and narrow cars, so narrow, in fact, that seats would be eliminated and the passengers, standing in a single line, would hold to a handrail to enable them to keep their feet. Moving across town at high speed, the journey would be so short, he claims, that seats would be superfluous. The long thin cars, would offer less wind resistance, and the space occupied by the support would be correspondingly reduced.

Speed on the ocean and in the air is getting an equal share of attention. The German Dornier factory, which has been building double-engined flying boats with success for several years, is constructing a transatlantic air liner in its Swiss factory. The ship, a twelve-engined monoplane, will have a wing spread of

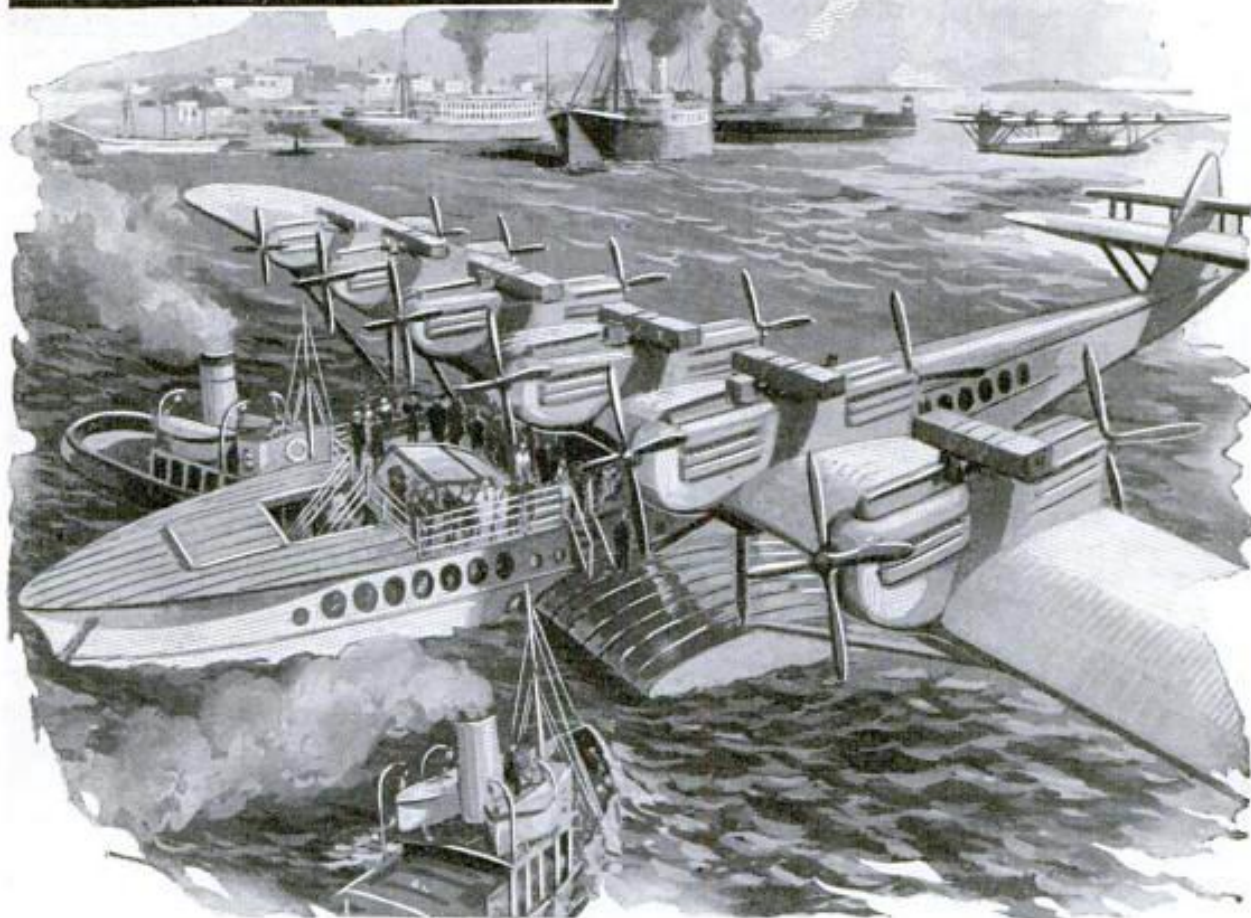
158 feet, will weigh forty-four tons, and carry fifty passengers, besides the crew. Following the usual Dornier design, the engines will be mounted in tandem pairs, one driving a tractor propeller in front of the wing, and its mate driving a pusher



structure would be streamlined to the same shape.

Another transatlantic project proposed in France is a combination of surface boat with short airplane wings and air propellers. A small craft of this type recently crossed the English channel in forty minutes. It combines the lifting effect of the airplane wings with a glider hull, so that, at full speed, it rides the surface of the sea instead of plowing through the water, thereby reducing friction. The wings are not large enough to actually lift the craft off the water.

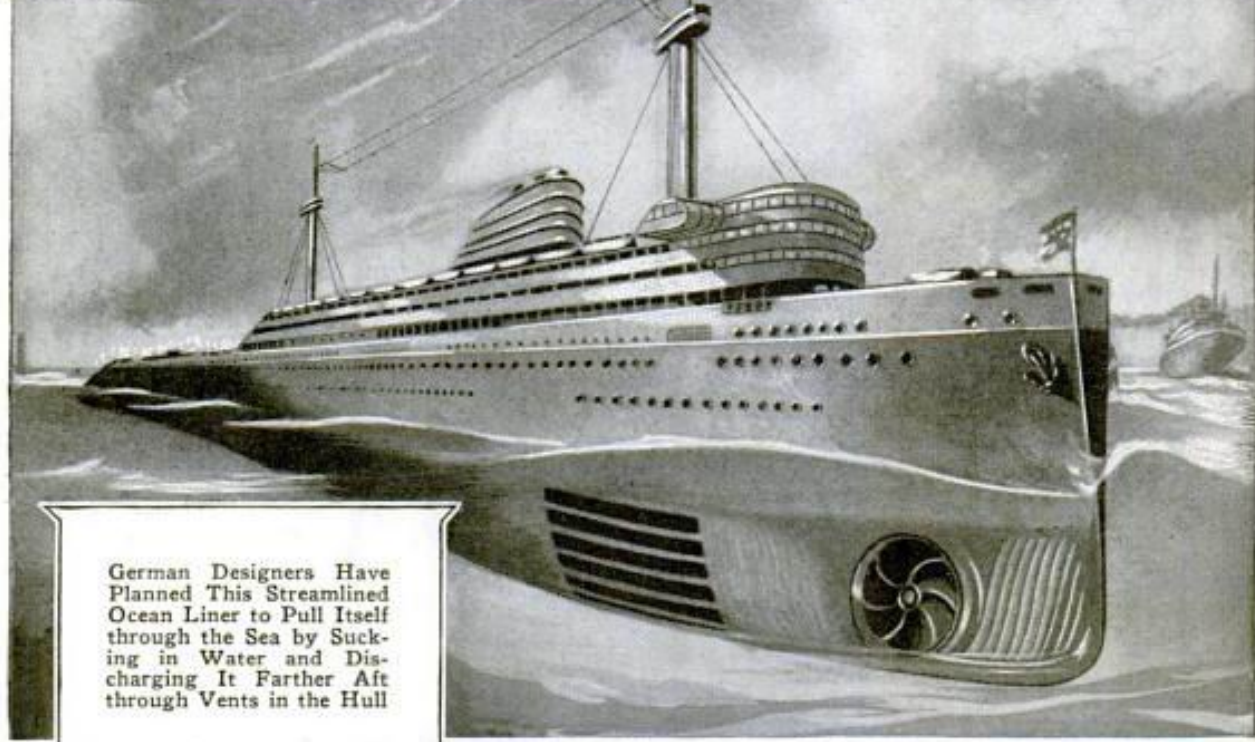
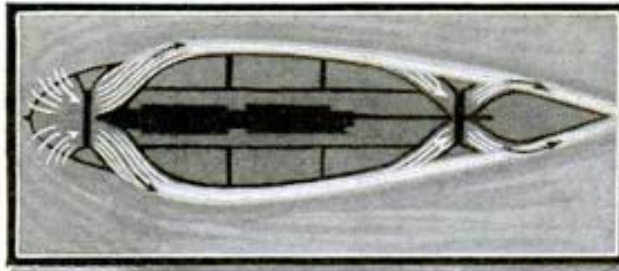
Two French engineers, Hirschauer and Talon, have invented a high-speed aerial cableway for transportation of mails, and are trying to interest the French government in it. They propose a series of tall towers, holding a suspended tubular



Twelve-Engined Flying Boat Being Built in Switzerland by the Famous Dornier Factory, and, Above, a Frenchman's Idea for a Three-Hundred-Mile-an-Hour Aerial Postal Service

600

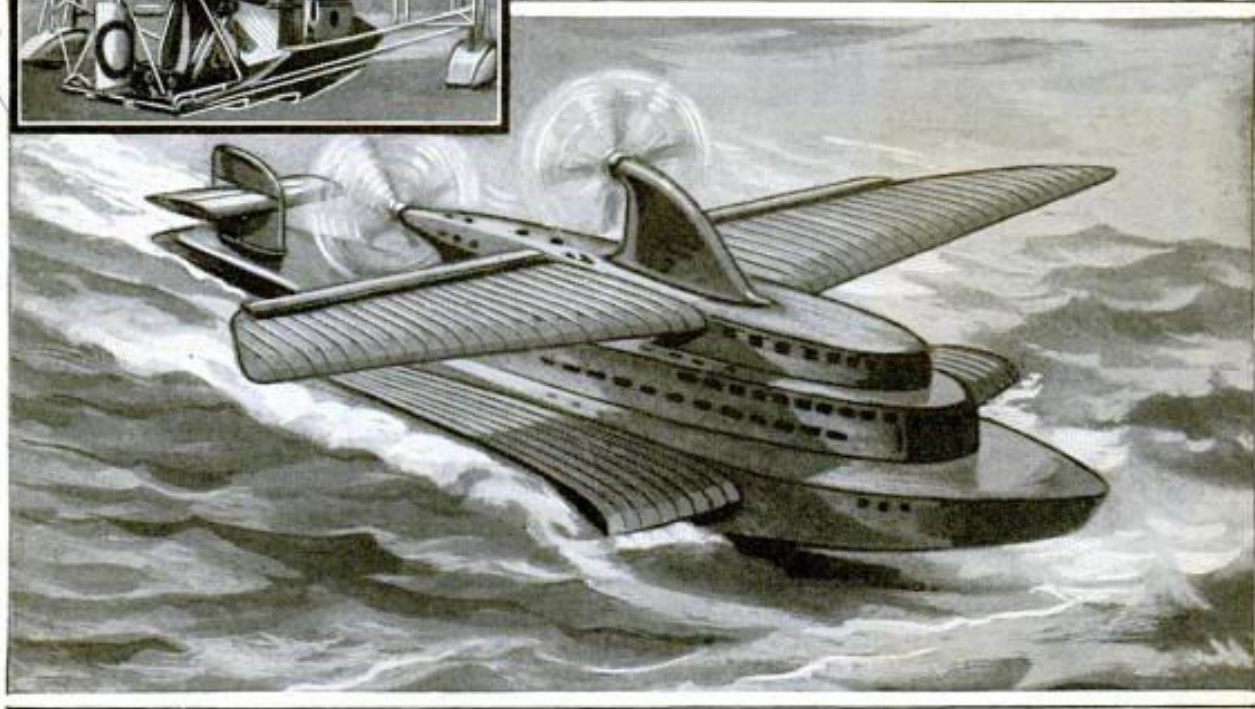
See idea see Jan. 1928 181



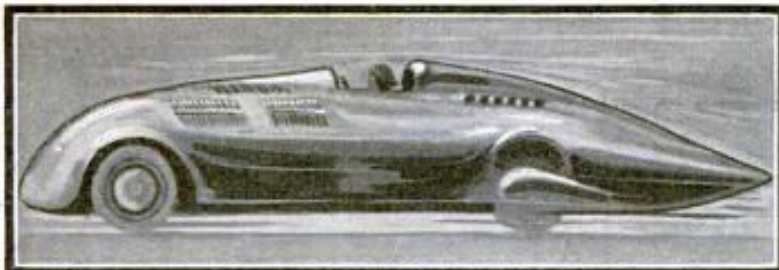
German Designers Have Planned This Streamlined Ocean Liner to Pull Itself through the Sea by Sucking in Water and Discharging It Farther Aft through Vents in the Hull



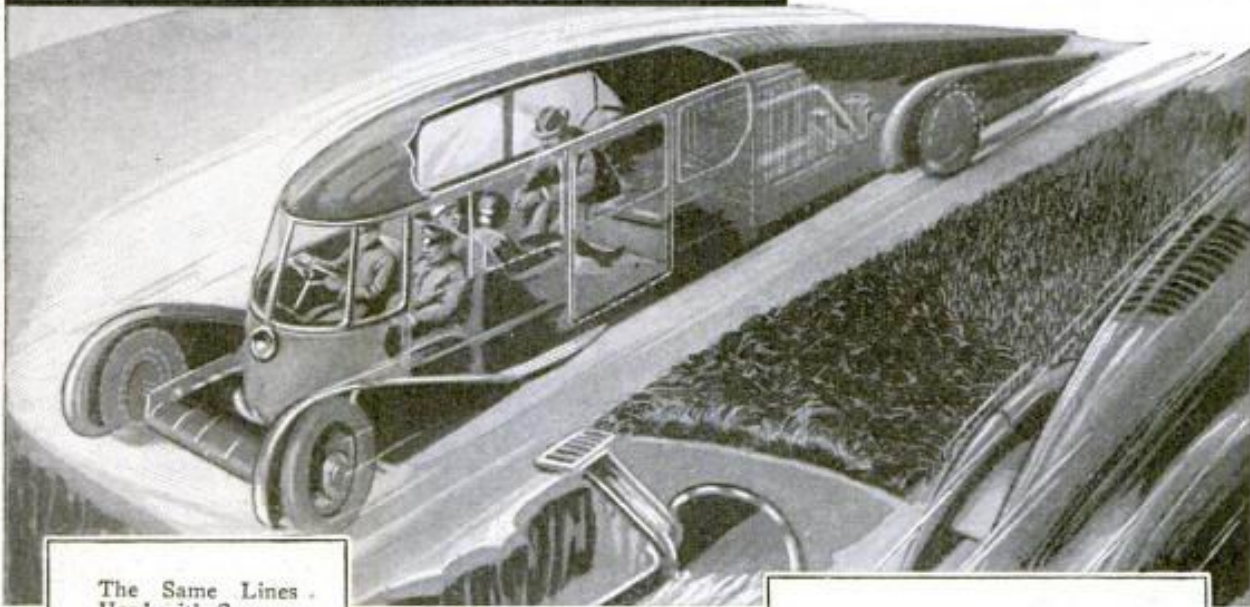
Left, This Queer Craft Is Not an Airplane, But a Hydroplane, Which Has Cut the Voyage from France to England to a Matter of a Few Moments; Below, a Proposed German Air Liner to Carry 200 Passengers across the Atlantic in Half the Time of the Fastest Steamers



600

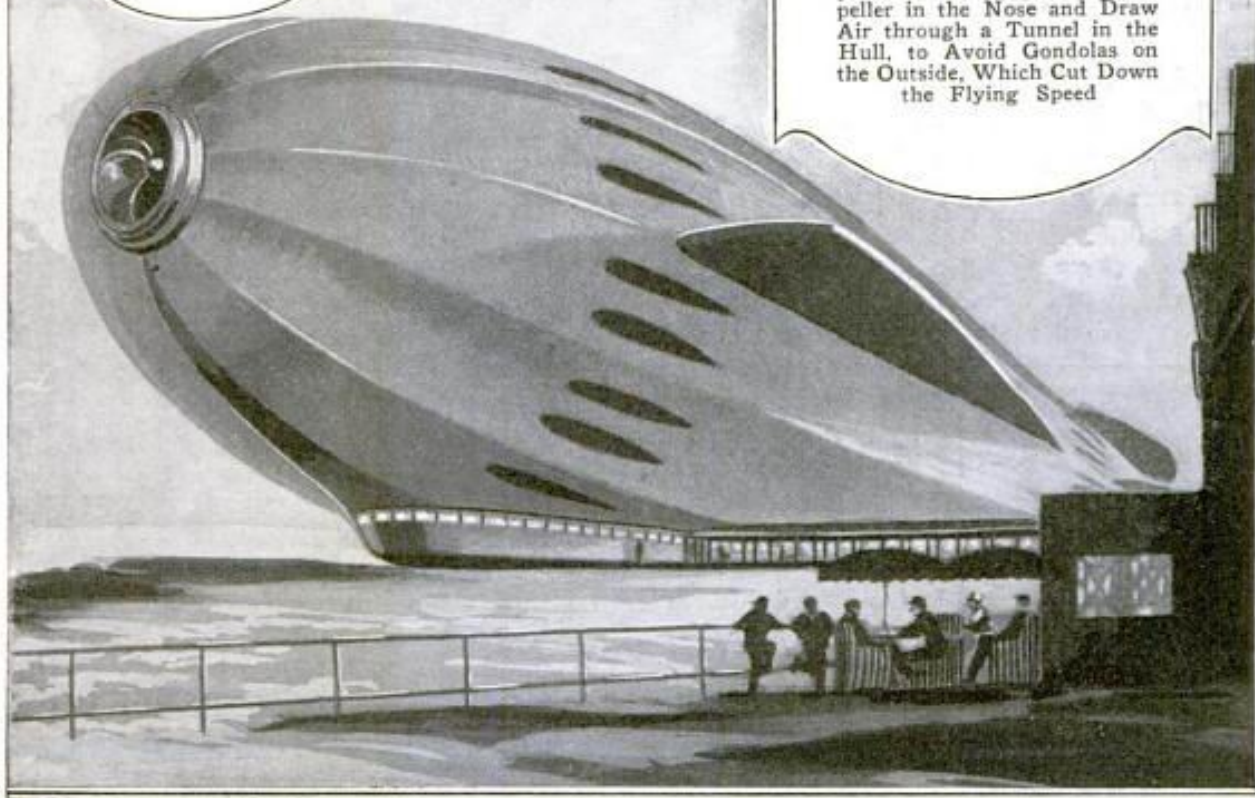


cage, in which torpedo-shaped mail containers, eight or ten feet long, would be driven by electric motors at 200 miles an hour. The construction, it is claimed, is cheaper than underground pneumatic tubes.



The Same Lines Used with Success in Maj. Segrave's Racer Have Been Applied to the Teardrop Motor Cars Built Abroad for High-Speed Operation

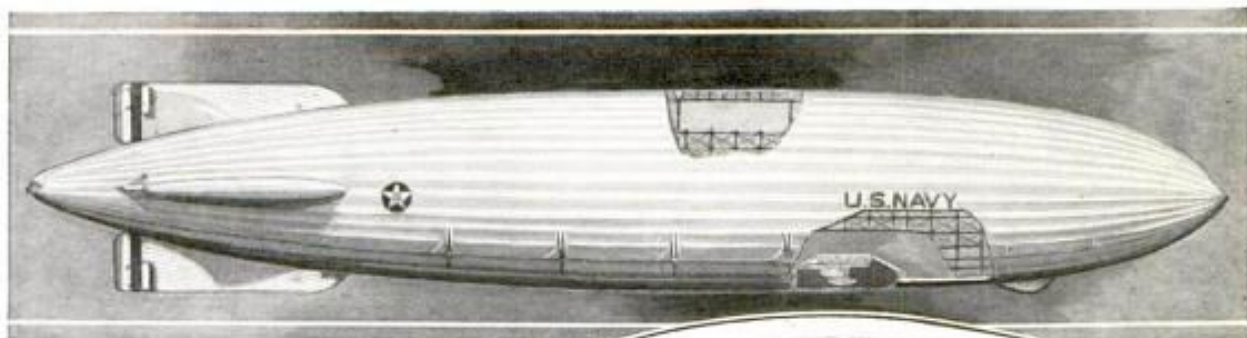
Several Inventors Are Experimenting with Changes in Airship Design, to Improve on the Cigar-Shaped Hull Used by Count Zeppelin Since Wind-Tunnel Tests after the War Showed It Was Not Altogether Perfect; One Proposal Is to Mount the Propeller in the Nose and Draw Air through a Tunnel in the Hull, to Avoid Gondolas on the Outside, Which Cut Down the Flying Speed



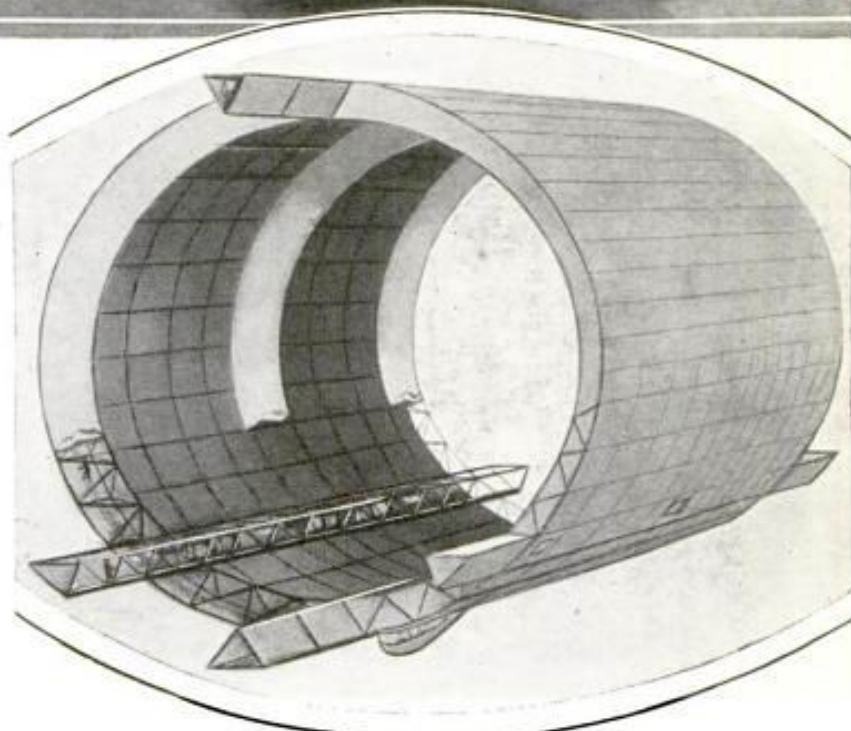


One of the Navy's Proposed New Airships, the "GZ-1," Compared with the "Los Angeles," the Army's Largest Semirigid "RS-1," and a Pony Blimp; the New Ships Are to Be 756 Feet Long and Have a Gas Capacity of Six and a Half Million Cubic Feet

AIRSHIPS TO HAVE TRAPEZE FOR CATCHING PLANES



Five scouting airplanes will be carried in each of the two huge dirigibles planned for the United States navy, and to provide the best equipment for handling the planes, interesting tests are being conducted with the "Los Angeles" and an observation plane. The latter unit has been fitted with special hooks over its wings for suspending it from a triangular trapeze attached to the frame structure of the dirigible. In actual practice, the plane would fly under the big ship, and the hooks would be attached to the trapeze,



Drawings of Proposed Dirigible for the Navy; Note Airplane Compartment and the "Cat Walks" the Full Length of Ship

which would then be used to swing the plane up into its hangar in the framework of the dirigible. To launch the airplane, the locks that hold it when it is finally in place, would be automatically released, allowing the plane to drop down in position for flight. The two new dirigibles, the "ZRS-4" and the "ZRS-5" will each have a gas volume of 6,500,000 cubic feet, will be 785 feet long and, at fifty knots, can cruise 9,180 miles without refueling. Each will have eight motors with a total capacity of 4,480 horsepower. An interesting feature of the engines is that they will be housed inside the body of the ship to decrease wind resistance and to give greater safety. The propellers will be driven through transverse shafts and their axles can be turned into the vertical position to exert an up or down thrust to assist in taking off and landing. Access

to all parts of the ships will be afforded through three passageways.

KNIFE TO OPEN PAPER CARTONS PREVENTS DAMAGE

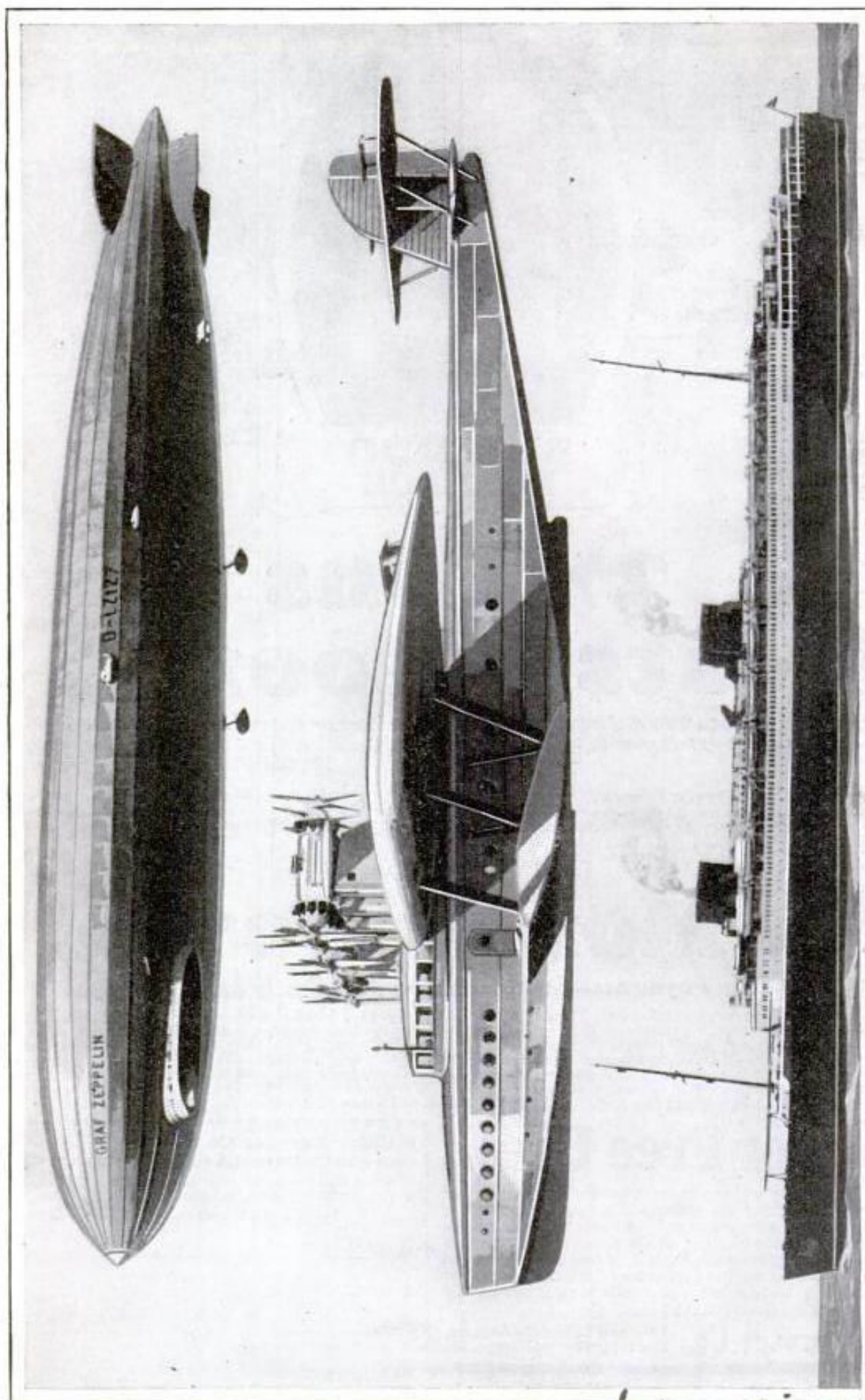
Paper containers are opened easily and quickly with a special knife that prevents damage to the contents and leaves the box in such shape that it may be used for reshipping. The cutting blade is held in a guide or shoe which keeps it from penetrating far into the carton, as some-



times happens with an ordinary knife. The blade may be removed for sharpening, and the tool is safe and strong.

Harley Clark, Inc. Co.
 Merline, Circa

3328



International

Germany's Peace-Time Triumphs of the Air and Sea; the "Graf Zeppelin," the Big 100-Passenger Dornier Seaplane, Propelled by Twelve Motors, and the Steamship "Bremen," Breaker of Ocean Speed Records; These Three Huge Units Promise a Complete Change in the Picture of International Transportation

Harnessing AMERICA'S Wildest



One of the switchboards in the control room at Boulder dam from which the flow of power is regulated

FOR generations the raging Colorado, rushing through its mile-deep canyons, enjoyed the evil distinction of being America's most unruly river. In the spring it descended on fertile desert lowlands as a roaring torrent. In the summer when this parched soil cried out for water, the surly stream dwindled to a sluggish creek.

Today this renegade among rivers has been tamed. Imprisoned behind the massive concrete and steel wall of Boulder dam, the once ungovernable stream has become so docile that its former wasteful and destructive energy has been harnessed to do monumental tasks—to turn the wheels of industry hundreds of miles distant, to augment the water supply of the Los Angeles metropolitan area and to irrigate the rich farmlands along the river below the dam and in the Imperial valley.

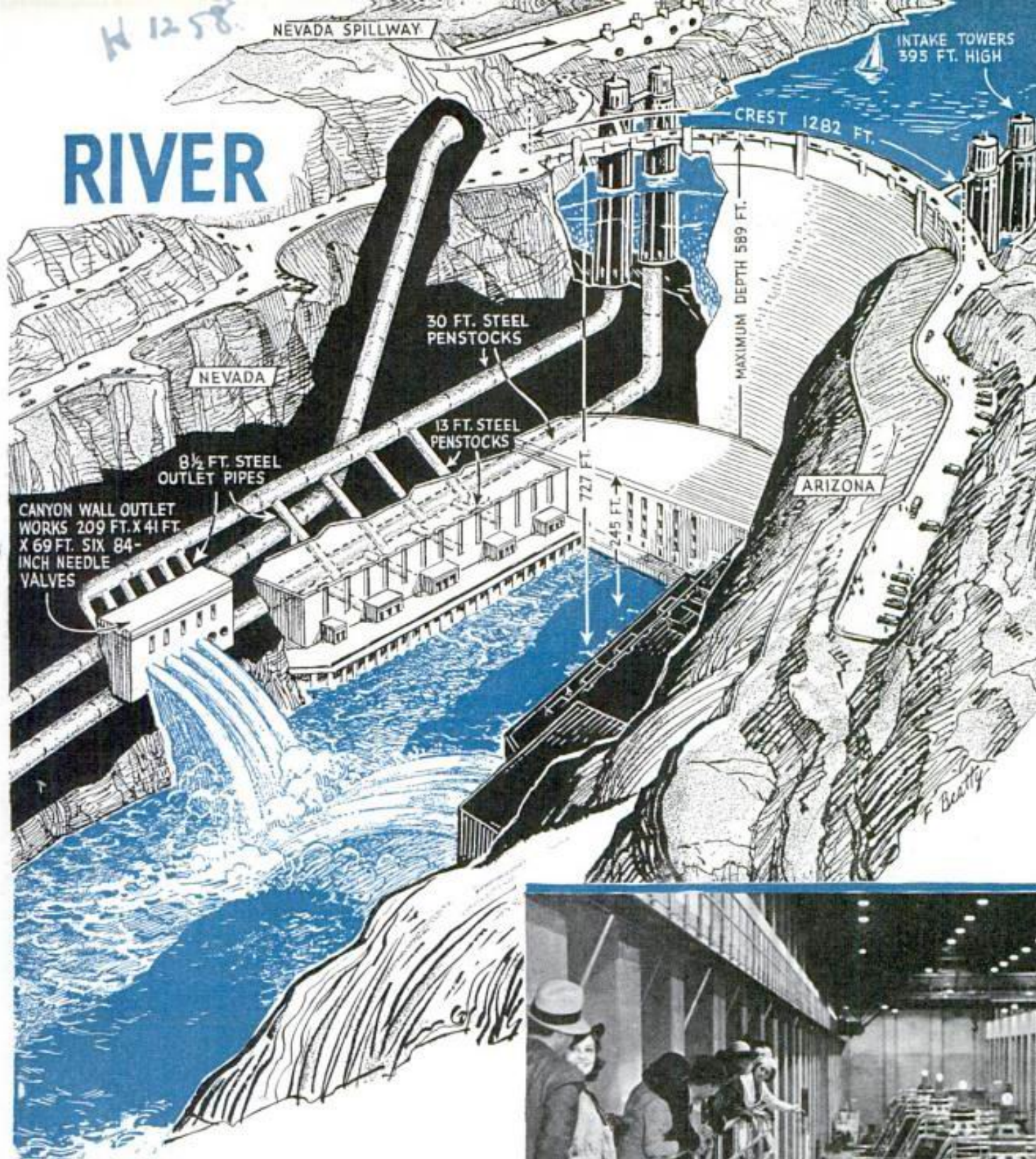
In fact, so thoroughly has the Colorado been conquered that the puny hands of a few score of men, backed by the mighty strength of the dam, now direct the almost limitless force of this 1,700-mile river and control the flow of billions of gallons of water almost as easily as you control the flow of water at your kitchen faucet.



NEVADA SPILLWAY TUNNEL 50 FT. IN DIAMETER 2200 FT. LONG

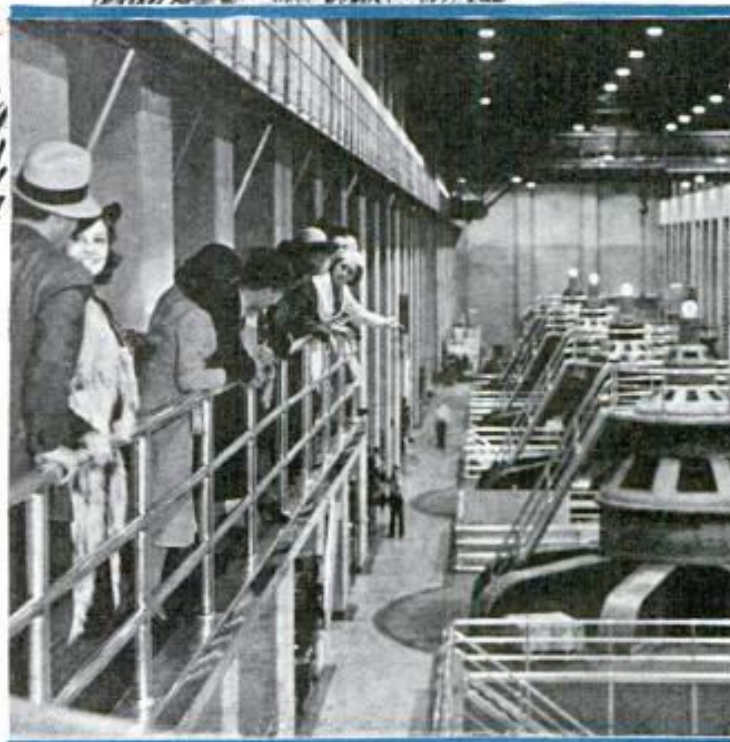
In the kitchen you turn a little valve and a jet of water under a few pounds pressure gushes out. At Boulder dam there are more than 21,500,000 pounds of gates and valves, a few weighing as much as 500,000 pounds. Opening such valves releases a veritable Niagara under pressures of hundreds or even thousands of pounds. Yet little more effort is required to open a

RIVER



valve weighing several tons than is needed to turn the steering wheel of your car, because the water does most of the work. In fact, operating some of the valves and gates requires no manual effort at all. They work automatically.

The nerve center from which the flow of water for all purposes is directed is the water master's office. No water will ever flow over this dam. Instead it is carried through huge steel penstocks from eight and one-half to thirty feet in diameter. The water enters through gates in each of



Some of the huge Boulder dam generators and, above, drawing showing how Nevada side of Boulder dam works. The Arizona side has a similar layout



Sun in eclipse, with vast flames of incandescent hydrogen gas sometimes rising a half million miles. In total eclipse, the sun is surrounded by a halo called the corona.



6 MINUTES EXPOSURE



15 MINUTES EXPOSURE

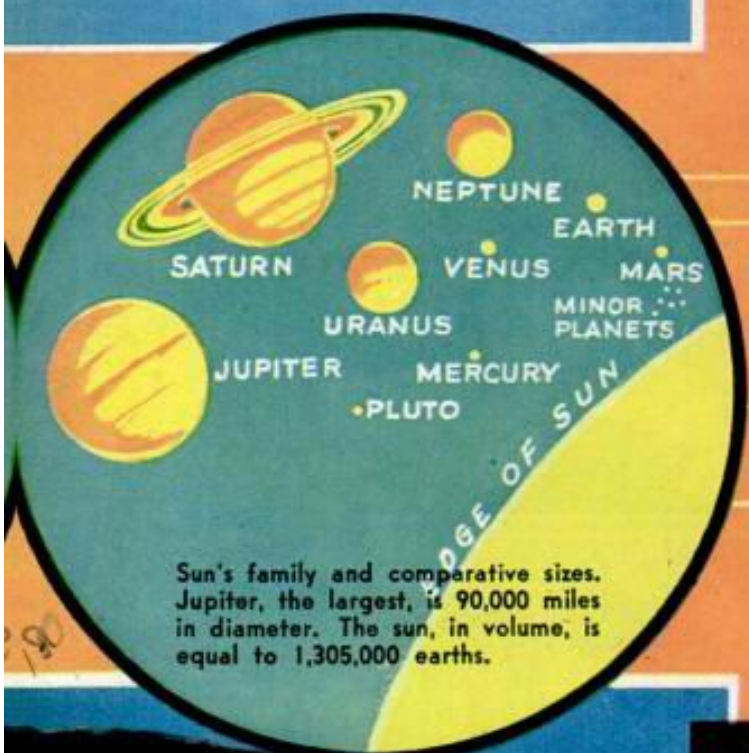


37 1/2 MINUTES EXPOSURE

Four pictures taken through sixty-inch telescope at Mt. Wilson Observatory, showing how extending the exposure time brings in more stars.



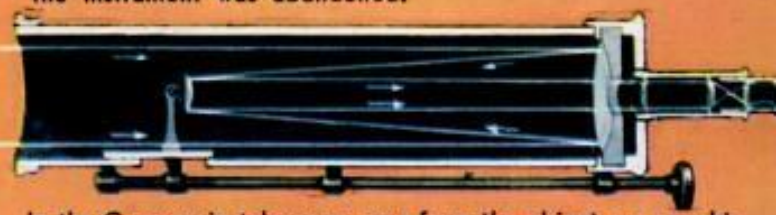
94 MINUTES EXPOSURE



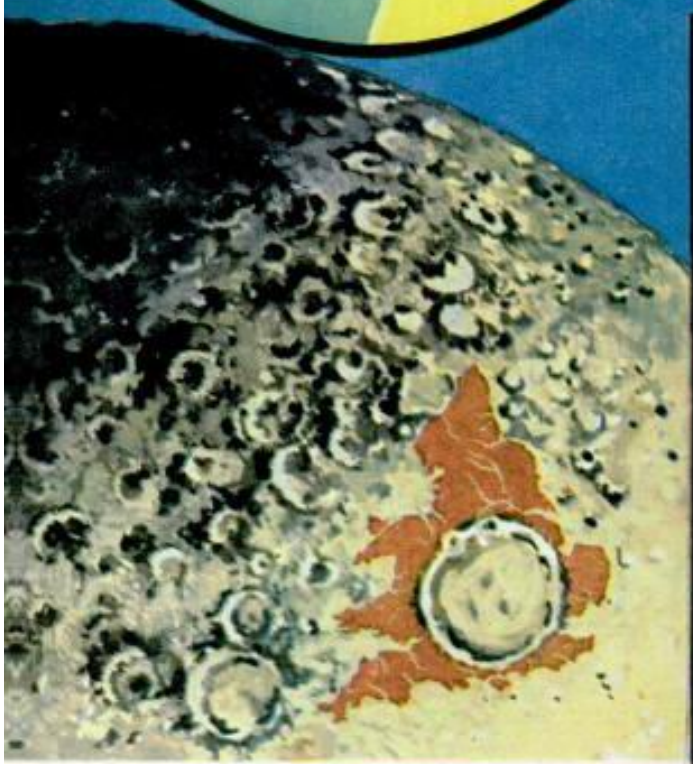
Sun's family and comparative sizes. Jupiter, the largest, is 90,000 miles in diameter. The sun, in volume, is equal to 1,305,000 earths.



Telescope invented by Sir William Herschel had a concave twenty-four inch mirror which was slightly tipped. Image was formed at eyepiece. Slanting mirror caused distortion and the instrument was abandoned.



In the Cassegrain telescope, rays from the object are caught by large concave mirror near eyepiece and reflected to small convex mirror, which reflects them through hole in mirror to observer's eyepiece.



Moon as seen through 100-inch telescope at Mt. Wilson observatory. Size of craters is shown by map of England drawn to same scale.



Eighteen-inch Schmidt telescope in use on Mt. Palomar, Calif., as an exploring telescope for finding mysterious super novae stars.

Mystery spot on Jupiter, estimated to be 30,000 miles long and 7,000 miles wide.

Strange white spot which was discovered on Saturn in 1933.



Ordinary terrestrial telescope presents image right side up, unlike astronomical telescope from which lenses are omitted to obtain more light.



Newton telescope in which rays are caught by concave mirror, reflected back to prism which then reflects them at right angles. Eyepiece is at side.



Gregorian telescope is like Cassegrainian except that image is reflected back to concave mirror instead of convex.



Visitors from space approaching the earth, with large meteor at bottom and comet at top right.

COATING OF ALUMINUM

11 FT RADIUS 16'8"

WEIGHT SAVING RECESSES

BASE PLATE

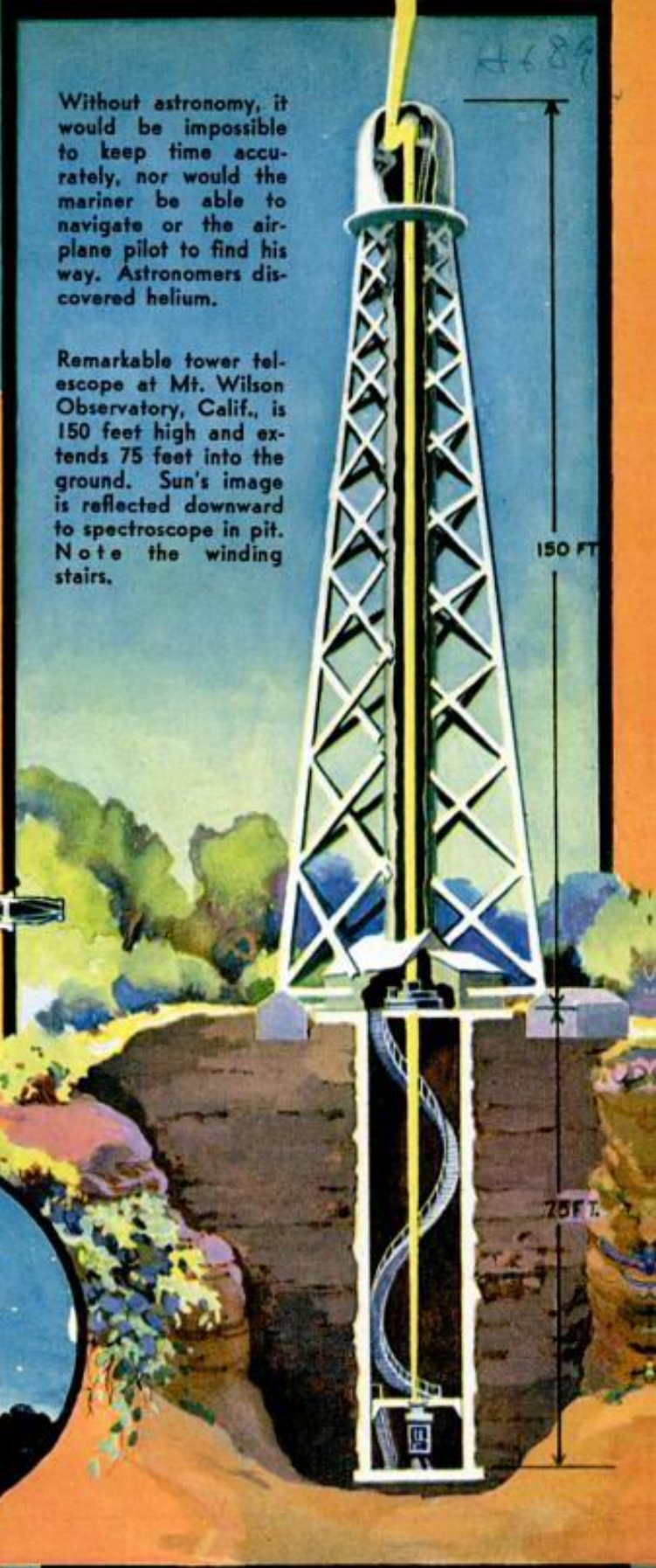


HOLE FOR EYE-PIECE

Largest piece of glass ever cast, 200-inch mirror for new telescope. It weighs twenty tons and smoothing its surface to one millionth of an inch will take two years.

Without astronomy, it would be impossible to keep time accurately, nor would the mariner be able to navigate or the airplane pilot to find his way. Astronomers discovered helium.

Remarkable tower telescope at Mt. Wilson Observatory, Calif., is 150 feet high and extends 75 feet into the ground. Sun's image is reflected downward to spectroscope in pit. Note the winding stairs.



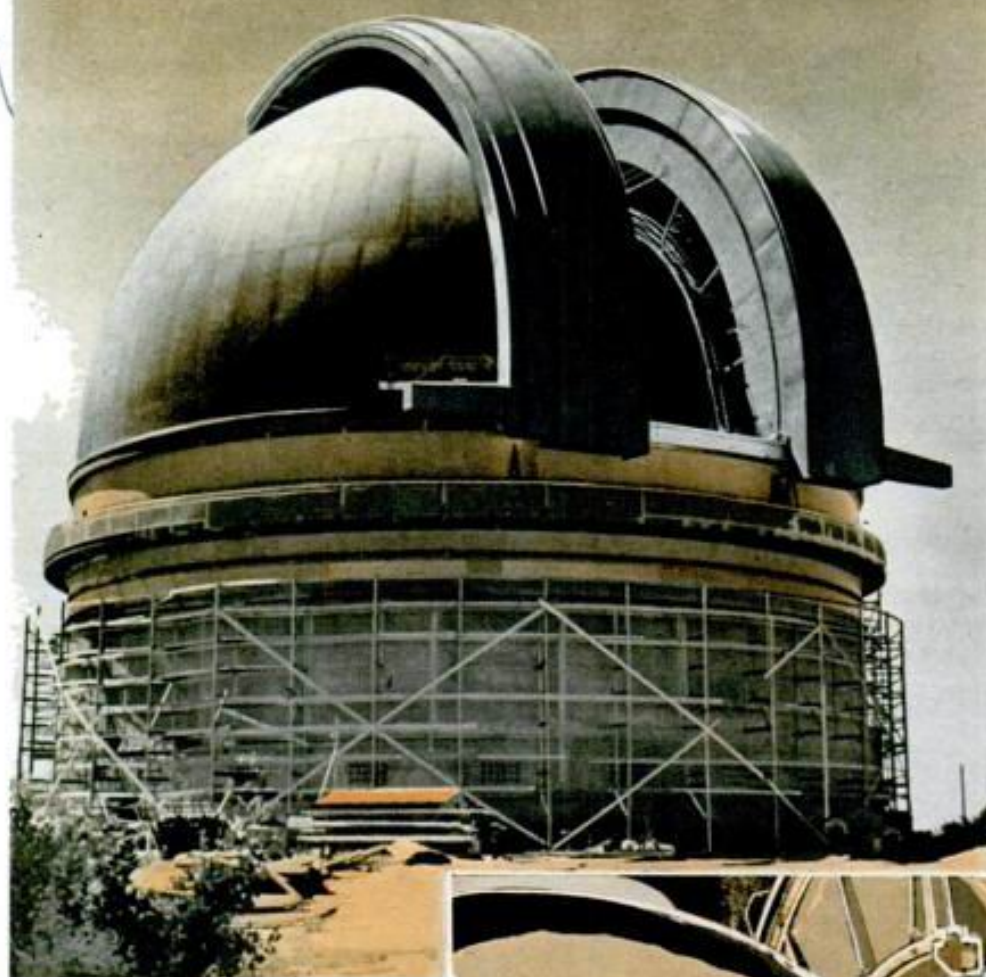
150 FT

75 FT



New 200-inch telescope may reveal whether these are roads or canals on map of Mars drawn by the late Prof. P. Lowell.

14689

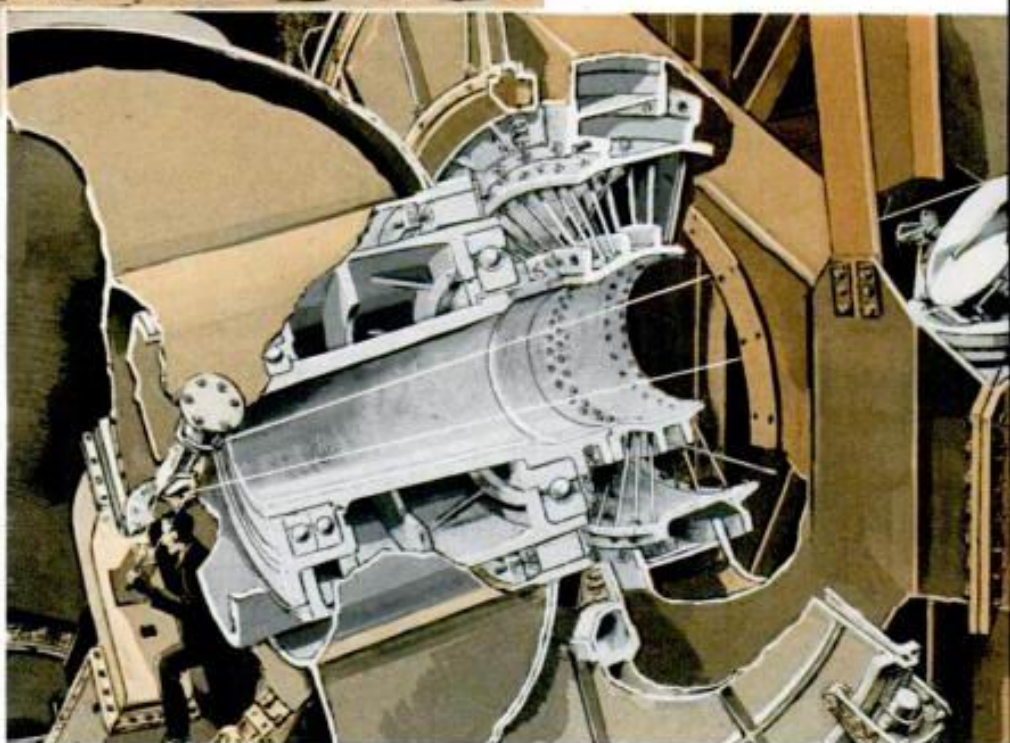


FOURTEEN stories high, the two-million-pound dome is really a dome within a dome, each coated with aluminum and separated by a four-foot air space for insulation. It revolves on thirty-two four-wheel trucks of railroad type which roll on a track around the wall. Below, cutaway drawing of declination trunnion. Bottom, twelve exposures of Saturn made at Mt. Wilson observatory.

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concentrated light from the mirror, will be made at the prime focus, the point above the mirror where the reflected light is brought to a focus by the mirror's curve. The observer will be stationed inside a small bullet-shaped house suspended inside the skeleton barrel at that point. The house reduces the amount of starlight falling on the mirror down below but the astronomers estimate that this method will be more efficient than the diagonal mirror usually placed at the prime focus to reflect the rays out of the barrel to an observation point.

By substituting a mirror for the observer's cage at the prime focus and reflecting the gathered light back down through a hole in the center of the 200-inch mirror to an observation point below, a different optical effect is achieved. This Cassegranian focus will be used for



spectrographic and photographic observations. In still another hook-up, known as the coudé, the light is reflected from the prime focus back to a diagonal mirror suspended above the giant eye and is "piped" by several other mirrors to a constant temperature vault where special spectrographic work will be conducted. In this setup the light will be reflected from as many as five mirrors in the optical train. A jib crane, oper-



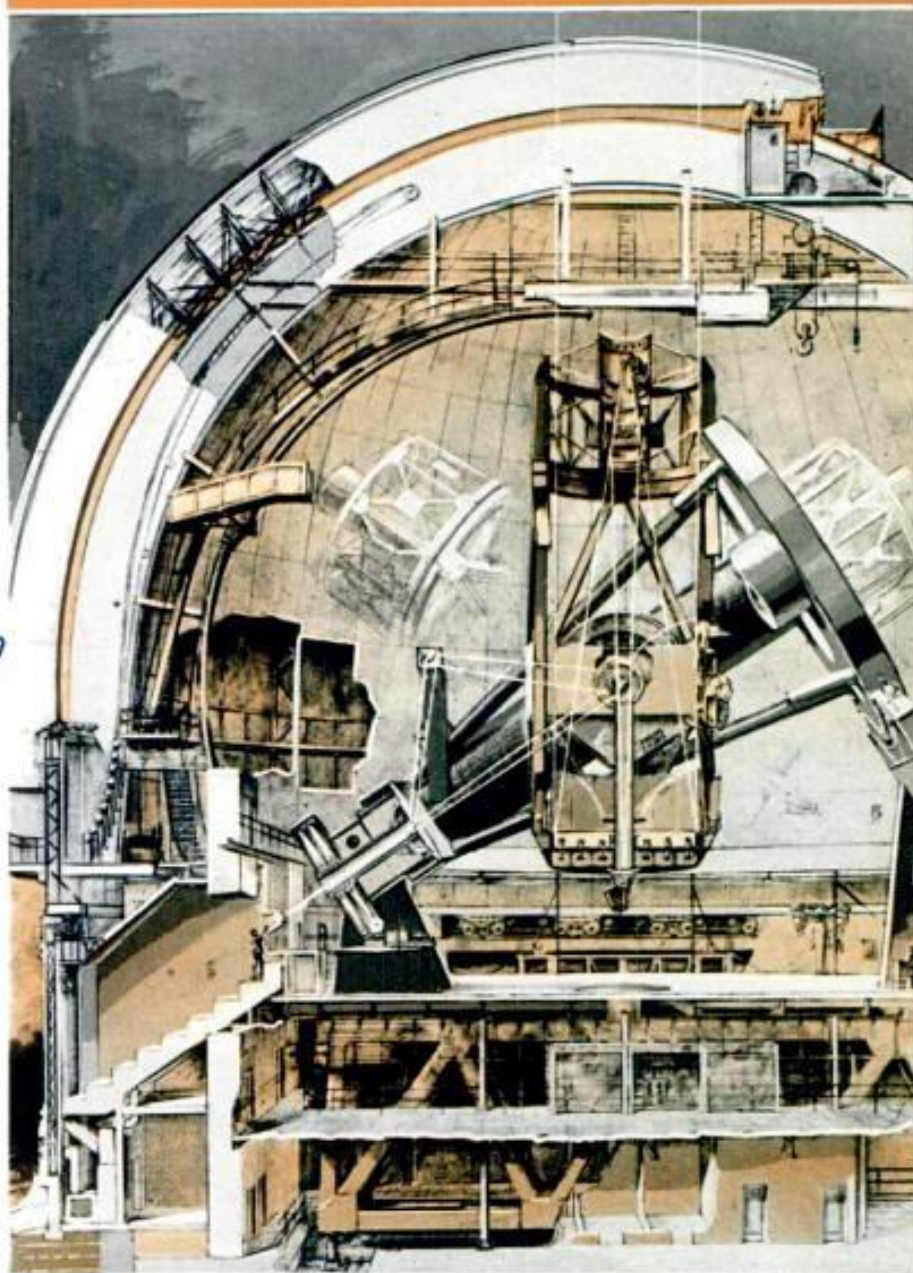
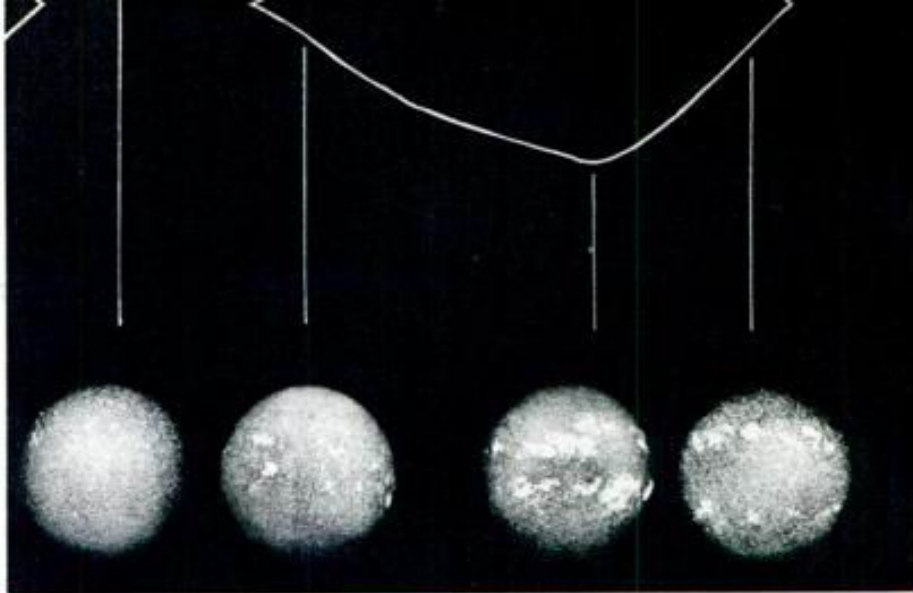
14689

ated by electric motors, is being mounted on the great telescope for moving the optical parts.

Astronomers estimate that for many kinds of observations the telescope will be twice as powerful as was first planned simply because of the great improvements that have been made to auxiliary instruments since the telescope was first projected. Photoelectric equipment, correcting lenses, and the sensitivity of photographic emulsions all have been improved vastly, increasing the scope of all astronomical telescopes.

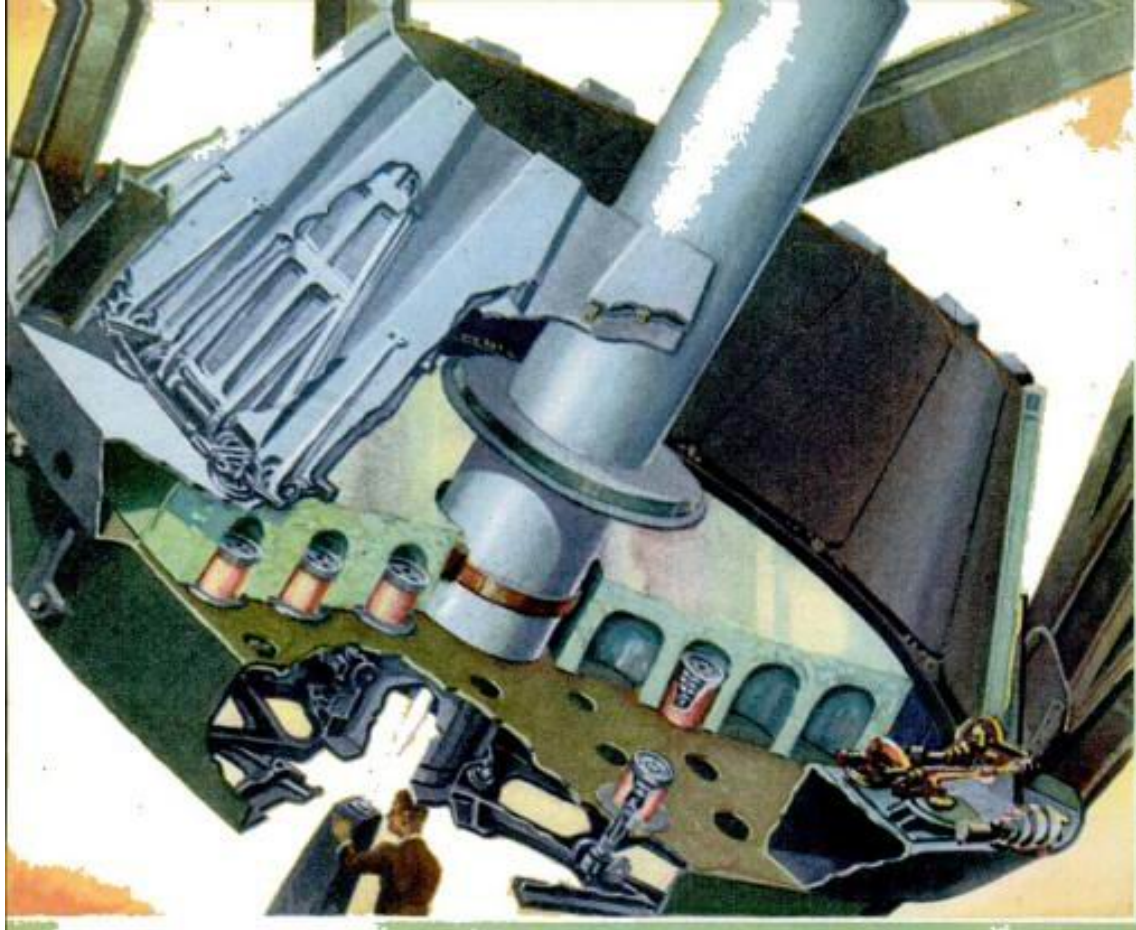
One of the great strides is a new superthermometer invented by Dr. John Strong of the Institute's astro-physics staff. This instrument, called a radiation pyrometer, resembles a small telescope and is equipped with rock-salt and quartz lenses that screen out all except infrared radiations. These red rays fall on two thin gold leaves attached to the wires of a tiny galvanometer. Aside from its astronomical importance the instrument can take the temperature of a person several miles away and measure the surface heat of clouds or balloons.

New ideas, new materials, and new methods were all necessary in building the titan of telescopes. Accuracies never before attempted on a large scale were imperative. Pointing the huge instrument on a star and holding the image still during the star's slow movement across the night sky is comparable to keeping a gun trained continuously on a target two inches in diameter that is eight miles away and that moves at a speed of three feet per second. To stay on the star the telescope must move on two axes at the same time and the great dome above it must also revolve so that the telescope always points through the open slot in the roof. The different



CURVE of single sun-spot cycle is shown at top with four calcium spectroheliograms showing appearance of sun at phases of cycle, observed at Mt. Wilson. Phantom drawing below gives impressive glimpse of immensity and intricacy of Mt. Palomar telescope.





14689

MIRROR, cell, support and cover are seen in cutaway drawing at left. Below, an astronomer inspects the small polished mirror which is used to reflect light from the stars to a spectrograph, where the scientist reads the thin spectral lines to learn the elements of which stars are made.

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moving parts weigh hundreds of tons each and yet the slightest vibration would cancel the value of the telescope. For some kinds of research the image of a star, picked up by the great light-gathering eye, must pass through a slit one thousandth of an inch wide. Any vibration would throw the image off. Once, during an observation at another observatory, the vibration from a one and one-half-horsepower concrete mixer several blocks away was enough to disturb the instruments.

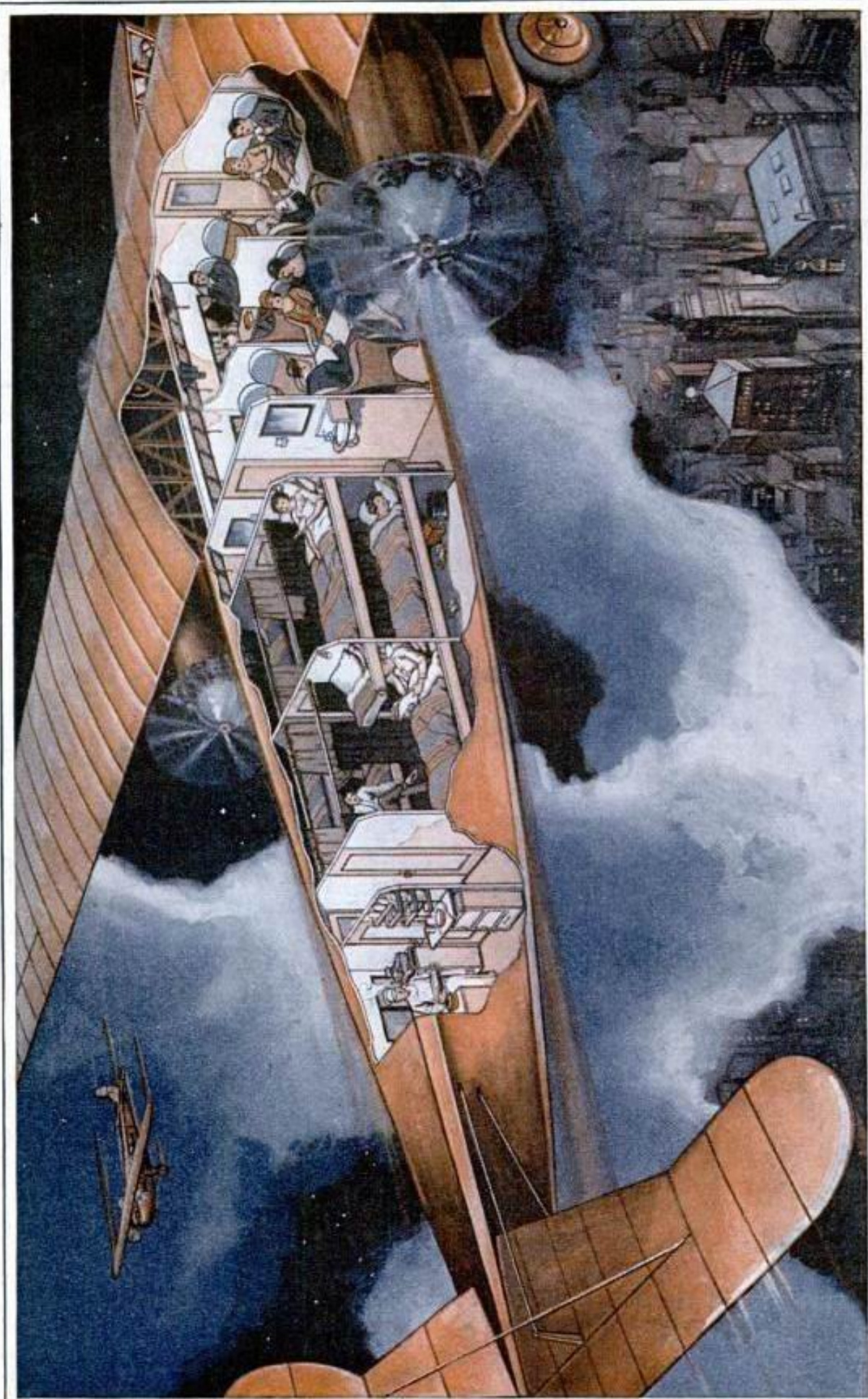
One of the most difficult feats was to arrange a smooth way of turning the big 2,000,000-pound dome. Even a slight vibration such as would barely ripple a glass of water would be too much. The problem was solved by a new type of drive developed by Edmund G. Grant, associate engineer of the project. The dome is supported by thirty-two four-wheeled railroad-type trucks that travel on a track around the circular wall. Instead of using the conventional rack and pinion to turn the dome Grant created a new kind of friction drive, using four electric motors of seven and one-half horsepower geared vertically to huge rubber-tired motor-truck wheels that press against the dome.

(Continued to page 128A)



Fokker-Aircraft Corporation, 110 E 42nd, New York

26/0

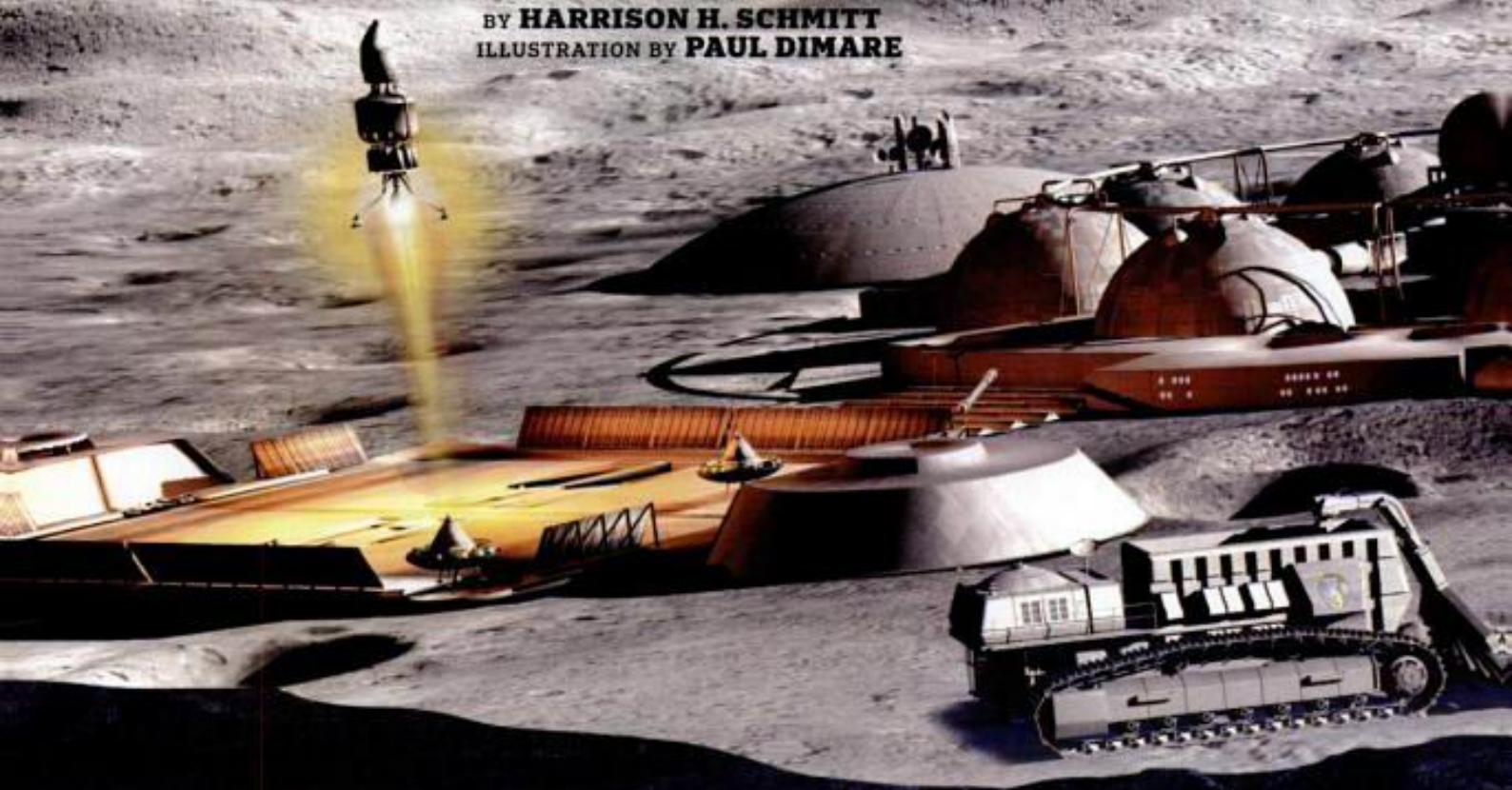


America's Biggest Air Liner, Now under Construction, Is This Four-Motored Fokker, with Berths for Sixteen or Seats for Thirty-Two Persons

Mining The Moon

An Apollo astronaut argues that with its vast stores of nonpolluting nuclear fuel, our lunar neighbor holds the key to Earth's future.

BY **HARRISON H. SCHMITT**
ILLUSTRATION BY **PAUL DIMARE**



Apollo 17 astronaut Harrison Schmitt left the moon 32 years ago with 244 pounds of rocks and an abiding desire to see humankind continue its exploration of space. Now, in an exclusive essay for **POPULAR MECHANICS, Schmitt explains why the time is right for America to return.**



FUTURE MINERS: Robotic equipment would scrape and refine lunar soil. Helium-3 would be sent to Earth aboard a future space shuttle or perhaps be shot from an electric rail gun.

Living Off The Land

Exploration of the solar system will be fueled by materials found scattered across asteroids, moons and planets.

Moon

The discovery of a helium isotope, helium-3, on the moon has given scientists ideas on how to produce electricity far more efficiently than with hydrocarbons or current nuclear plants. The large amounts of energy would come without danger of releasing radioactive substances into the atmosphere.

Mining the lunar surface would not be cheap; the investment would be comparable to building a major transcontinental pipeline.



Mars

Studies conducted by NASA and others have determined that water, rocket propellant and chemicals needed to sustain a human outpost could be manufactured from martian soil and ice caps (right). Future astronauts might set up production plants that expand as others arrive. Eventually, the Mars base could become a resupply base.



Asteroid belt

Moon

Earth

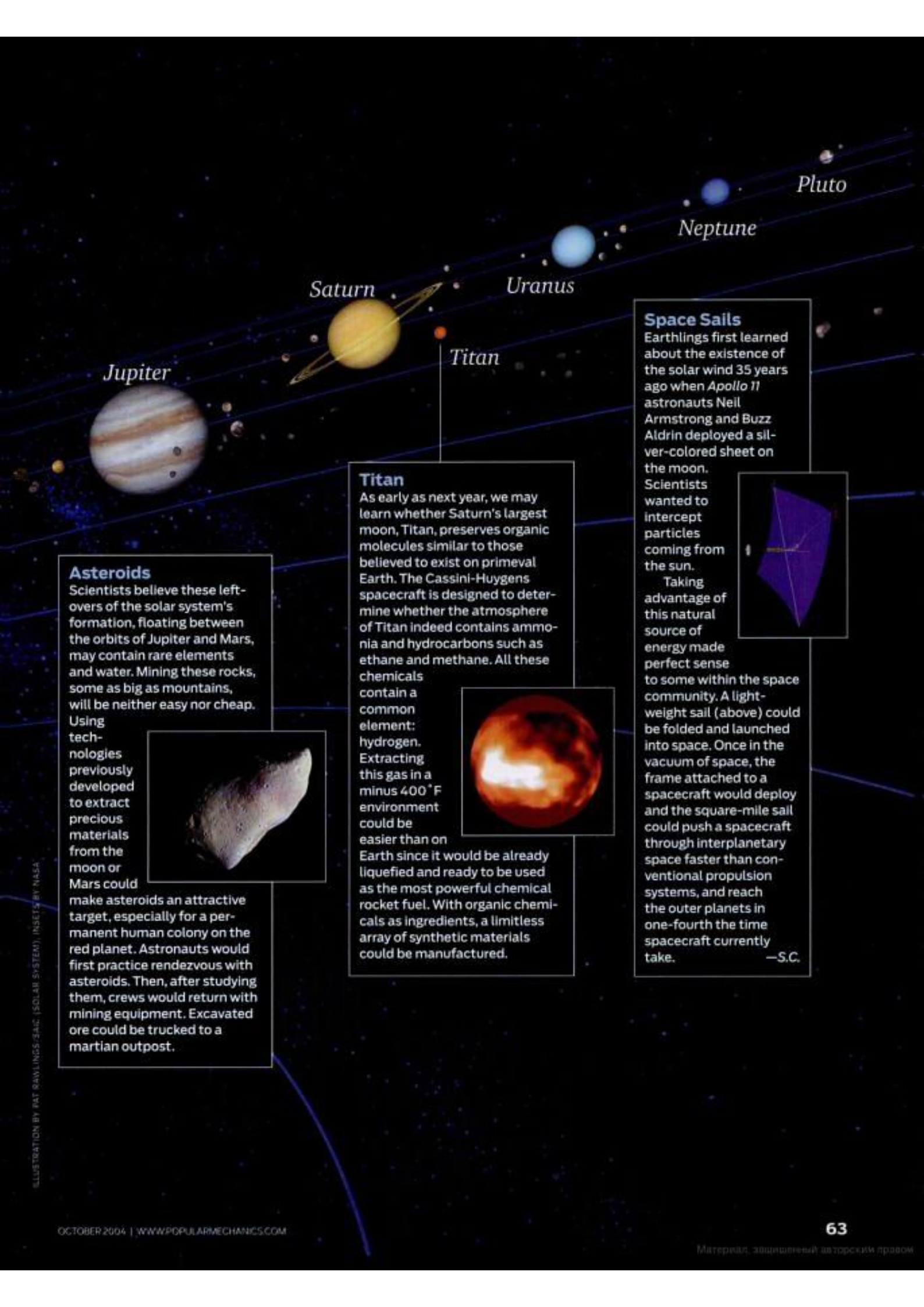
Mars

Venus

Mercury

Sun

*Solar flare
generating
solar wind*



Jupiter

Saturn

Titan

Uranus

Neptune

Pluto

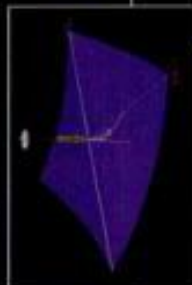
Space Sails

Earthlings first learned about the existence of the solar wind 35 years ago when *Apollo 11* astronauts Neil Armstrong and Buzz Aldrin deployed a silver-colored sheet on the moon.

Scientists wanted to intercept particles coming from the sun.

Taking advantage of this natural source of energy made perfect sense to some within the space community. A lightweight sail (above) could be folded and launched into space. Once in the vacuum of space, the frame attached to a spacecraft would deploy and the square-mile sail could push a spacecraft through interplanetary space faster than conventional propulsion systems, and reach the outer planets in one-fourth the time spacecraft currently take.

—S.C.



Asteroids

Scientists believe these leftovers of the solar system's formation, floating between the orbits of Jupiter and Mars, may contain rare elements and water. Mining these rocks, some as big as mountains, will be neither easy nor cheap.

Using technologies previously developed to extract precious materials from the moon or Mars could

make asteroids an attractive target, especially for a permanent human colony on the red planet. Astronauts would first practice rendezvous with asteroids. Then, after studying them, crews would return with mining equipment. Excavated ore could be trucked to a martian outpost.



Titan

As early as next year, we may learn whether Saturn's largest moon, Titan, preserves organic molecules similar to those believed to exist on primeval Earth. The Cassini-Huygens spacecraft is designed to determine whether the atmosphere of Titan indeed contains ammonia and hydrocarbons such as ethane and methane. All these chemicals contain a common element: hydrogen.

Extracting this gas in a minus 400 °F environment could be easier than on Earth since it would be already liquefied and ready to be used as the most powerful chemical rocket fuel. With organic chemicals as ingredients, a limitless array of synthetic materials could be manufactured.



AMERICA'S SPACE PROGRAM: WHAT WE SHOULD DO NEXT

BY BUZZ ALDRIN

My thoughts about our next steps in space remain fundamentally the same as they were before the *Columbia* accident on Feb. 1. It has crystallized a bit more since serving as a presidential appointee on the U.S. Aerospace Commission. After the commission report was completed last fall, I began organizing a conference to discuss alternative approaches to space exploration. Tentatively scheduled for late October or mid-December, the conference will be part of the nation's celebration of the centennial of flight. The participants will include a symbolic representation of lunar astronauts, space experts and leading futurists. Broadcasting the event on C-SPAN and NASA TV will open deliberations to the public. Now, in the wake of *Columbia*, I believe that I cannot wait to have these alternatives introduced for wide consideration.

Crew-escape enhancement must be NASA's first priority. My colleagues at Starcraft Boosters have been working on a plan to upgrade the present fleet of orbiters with a crew-escape module. At any time from the countdown on the launchpad to re-entry, the crew-escape module could be separated from the orbiter and make a parachute landing.

The module's re-entry into the atmosphere would be semiballistic. An ablative heat shield, like those on the Mercury, Gemini and Apollo capsules, would protect the module during re-entry.

SPACE A parachute or parafoil would slow its fall to Earth and airbags would deploy to cushion the landing on land or water.

The addition of this escape module to the shuttle orbiter could be accomplished during periodic scheduled missions. The first module could be installed on the *Atlantis* orbiter, which is scheduled for an overhaul beginning in April 2004. But perhaps that is too early.

A high-priority, similar-designed crew-return module also could solve the crew-staffing problem aboard the International Space Station (ISS). Currently the station is limited to three, the number of people that can escape in the Soyuz capsule. Since a certain amount of hours must be devoted to routine station maintenance, having only a 3-person crew cuts extensively into time available for scientific experiments.



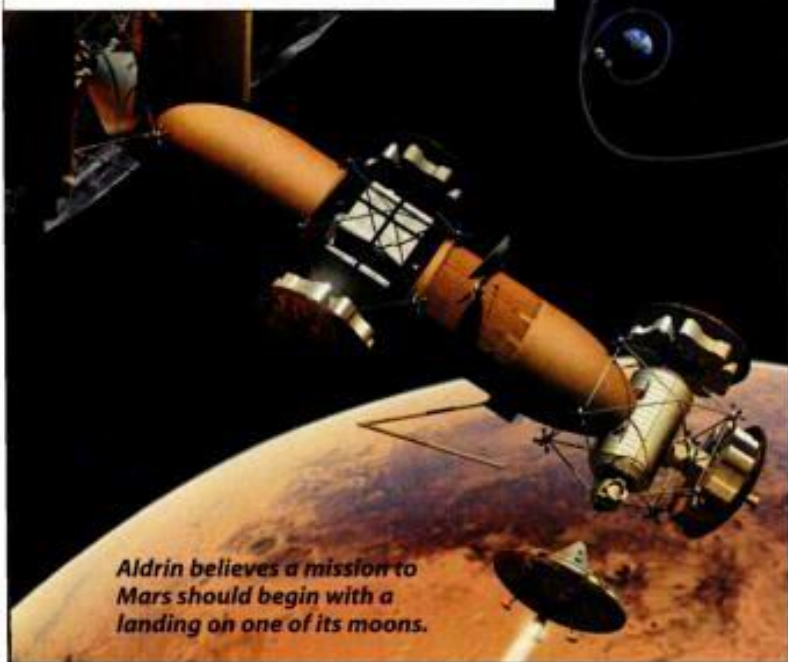
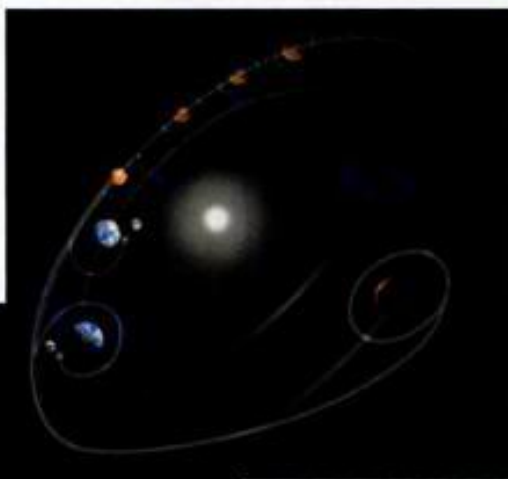
Buzz Aldrin was backup Command Module pilot for Apollo VIII, man's first flight around the moon. On July 20, 1969, he and fellow Apollo XI astronaut Neil Armstrong became the first humans to walk on the moon. Aldrin holds a doctorate in manned space rendezvous from the Massachusetts Institute of Technology. He currently heads Starcraft Boosters and is a leading voice in charting the course of future space efforts.



Starcraft has designed a fly-back-booster-based launch system to reduce costs.

With a crew-return module with six seats, the ISS could operate with a full crew after the shuttle returns to flight status. Modules could be transported to the ISS inside the shuttle cargo bay or launched unmanned atop a Delta 4.

Up to now, many people have believed that the purpose of the space program was science. But a science program, or one that is almost exclusively science, has never been that popular with the American people. What everyone has on their minds is some kind of exploration. To me, there are three destinations. The closest is the moon. There



Aldrin believes a mission to Mars should begin with a landing on one of its moons.

are many who think returning to the moon would be a good thing. I believe that lunar missions could lay the groundwork for Mars missions. The third destination could be an asteroid—in fact, this could be an attractive, early public commitment.

Mission To Mars

I do not use the question "Is there life on Mars?" as the reason for whether we should go. Mars is a deserving place for people to visit regardless

of whether life exists there. If there is no life on Mars, then we should probably ask, "Why isn't there?" Answering that question will take extensive investigation.

A more important question is: How should we explore Mars? I absolutely agree with the idea that when humans go to Mars, they should first go to the moons of Mars, not the planet itself. There is great logic in having human intelligence at the Martian moons. From there, astronauts could control robots on the planet's surface without the time delay that accompanies sending radio signals from Earth.

The chief advantage of first going to the red planet's moons is safety. If a mission-ending problem were to develop, it would be much easier to return to Earth from a moon. From the surface of the planet you would have to lift off, get into orbit, and rendezvous with a spacecraft that could bring you back. On

a moon, you are already in orbit and in a relatively secure place where you could be rescued at some time in the near future. Mars is not a place where you can come home at any time. Launch windows occur only every 26 months. I envision that the first mission would involve an 18-month stay on a moon, with a possible sortie to the surface of Mars itself by two or three astronauts. It is critical that we not go to Mars unless we are committed to a gradual, evolutionary buildup of a permanent base. We should not go once, twice or three times and then say we have done that and end exploration. It is too expensive an endeavor for it to be temporary.

Asteroids are attractive destinations for science

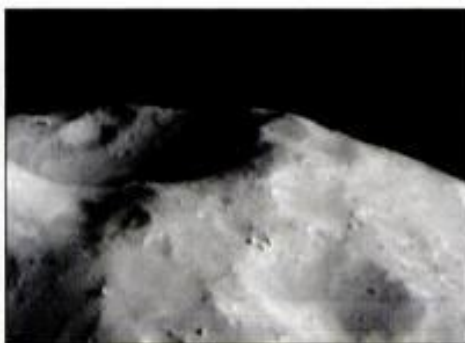


Aldrin envisions a multimodule space station, perhaps similar to the one shown here, as essential to future space exploration.

and the public at large. It may be scientifically valuable to establish a temporary human colony on one of these small planets, which you might visit a few times with human missions. Building a temporary base on an asteroid would be a good way to test the long-duration capabilities of operating on another planet and would not require the long-term commitment or permanence of a moon or Mars base.

Steering asteroids is an idea that captures the imagination of the public. Perhaps it is because we recognize that understanding and controlling asteroids could be pivotal to our long-term survival.

As an advanced civilization, we owe it to future generations to ensure the survival of the human race. That may involve having a growing settlement off Earth in case something happens to life here. It also means doing what we can to prevent a collision of an asteroid with the Earth's oceans or land mass. We need to do a lot of searching—it should be a combined effort between the Air Force and NASA with high-resolution telescopes that can observe near-Earth objects. We should catalog these objects and find out their composition. Then to assure ourselves that we know what to



To prevent collisions, Aldrin suggests learning to alter the paths of asteroids.

do if we find one that is on a collision course with Earth, we should visit an asteroid that is not on a collision course. Once there, we should demonstrate our ability to alter its course, without blowing it into pieces, then of course return potential resources to Earth.

Immediate Concerns

A more pressing survival need is that of the space program itself. Until the *Columbia Accident Investigation Board* makes its report, we will not know the fate of the present fleet of orbiters—whether they can be fixed and how long shuttles will have to be grounded. With half of the original orbiter fleet lost to the *Challenger* and *Columbia* accidents, these are indeed tough times for NASA.

These are equally crucial times for the future of the space program. NASA must resist the temptation for a quick fix, such as building a space plane that serves as a taxi to and from the space station on expendable launch rockets. We need to consider carefully our next destinations and the vehicles that will take us there. What we decide in the next two years will influence our space program for the next 20 to 30 years.

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EDGE
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**Littoral Combat
Ships Use Super
Speed To Smash
Seaborne Suicide
Squads**

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SCIENCE

STEALTH STRIKE FORCE

**America's top naval architects
compete to build a new class
of fast and deadly warship.**

BY JIM WILSON

Illustration by Tom Freeman





It happened in an instant. One moment, a perfectly routine refueling operation was under way. The next moment, the crew of the *USS Cole* was struggling to keep the missile cruiser afloat. For the family and friends of the 17 sailors who died, it was a tragedy beyond imagination. Aden, Yemen, was, after all, supposed to be a friendly port of call. For the navies of the world, the explosion delivered a powerful message: Modern warships are as vulnerable to suicide bomber attacks as tourists on crowded buses in Israel. What terrified admirals was not that a lone fanatic might repeat the Oct. 12, 2000, attack. The nightmare scenario was that a group of small boats would swarm a ship like killer bees. And that amid this confusion, an antiship missile would be fired at an aircraft carrier. Almost certainly the missile would be shot down by the carrier's on-board defenses. But in the upside-down world of international terrorism, the fact that someone could draw close enough to strike a crown jewel of the American fleet would be viewed as a stunning Al Qaeda victory.

DEFENSE

A Navy report issued after the attack on the *Cole* summed up the new threat to American sea power. "The current world environment requires us to operate in the backyards of tough, unyielding zealots. They don't want us there. They want us to stand off, farther and farther. To what degree do we influence events at sea and ashore, at a time and place of our choosing,



LOCKHEED MARTIN

if we are compelled to remain at arm's length for every power projection transaction?"

It did not take the Navy long to realize that it already had the rough outline for a new type of vessel to counter the threat posed by international terrorists. The Navy calls it a Littoral Combat Ship (LCS). "Littoral Combat Ships have been part of Navy concept development and experimentation since 1999," says a spokesman for the Navy Warfare Development Center (NWDC) in Newport, R.I. "In the Title X Global war game series, in the DARPA-sponsored Capabilities for the Navy After Next war games, in Fleet Battle Experiments and in other field and lab experiments, [LCSs] have had capabilities ranging from information operations to mine countermeasures to anti-submarine warfare to supporting special operations. Fleet commanders and battle group commanders have praised their attributes." DARPA refers to the Defense Advanced Research Projects Agency.

The idea for an LCS took a major step toward becoming an actual vessel with its inclusion in a Department of Defense planning document known as "Defense Planning Guidance: Fiscal Years 2003-2007." The report specifi-

cally directs the Navy to develop capabilities for dealing with the sorts of threats that could be mounted by rogue nations and international terrorists. The most important mission for the LCS is to keep the operating area around aircraft carrier battle groups clear of submarine-delivered and floating mines. Related to this is the need to improve the naval fleet's ability to destroy or evade large numbers of submarines operating in littoral areas, the shallow waters near shore.

According to the NWDC, several factors make the LCS a good vessel for conducting anti-submarine warfare in littoral waters. "Because of its high sprint speed, shallow draft, and its ability to operate over the horizon, the need for escort and protection is greatly reduced, allowing other assets to be freed up for power projection missions and other tasking. With active torpedo defense technology, the LCS can play a role analogous to an area air defense AEGIS ship. An LCS can sprint with towed or deployed anti-torpedo capability to counter attacks from quiet diesel submarines."

And, hearkening back to the fears raised after the *Cole* episode, the Navy wants to be able to destroy waves of small antiship

cruise-missile-armed boats or merchant ships, without drawing upon the aircraft on its carriers.

"The future for the U.S. Navy-Marine Corps team requires us to dominate the near-land battle space and provide access for our joint combat team," says Chief of Naval Operations Adm. Vern Clark. "Our enemies will continue to develop asymmetric means to stop us. LCS will be the asymmetric advantage that will allow us to dominate in this critical area. We need this capability as quickly as we can get it to the fleet."

Platform Approach

The LCS will be fast, lethal and incorporate the most advanced active and passive stealth technology. But most striking is the way naval architects will approach its design—as if they were creating an airplane rather than a warship.

Historically, American warships have been designed for specific tasks. The driving force behind a ship's design is its weaponry. A warship's very structure is part of the weapons systems it carries. And, that's exactly the opposite of what the Pentagon has in mind for the LCS.

In designing the LCS, the Pentagon wants architects to follow the model developed by the

***"The U.S. Navy wants to buy nine of the ships by 2009.
The LCS fleet could grow to as large as 60."***

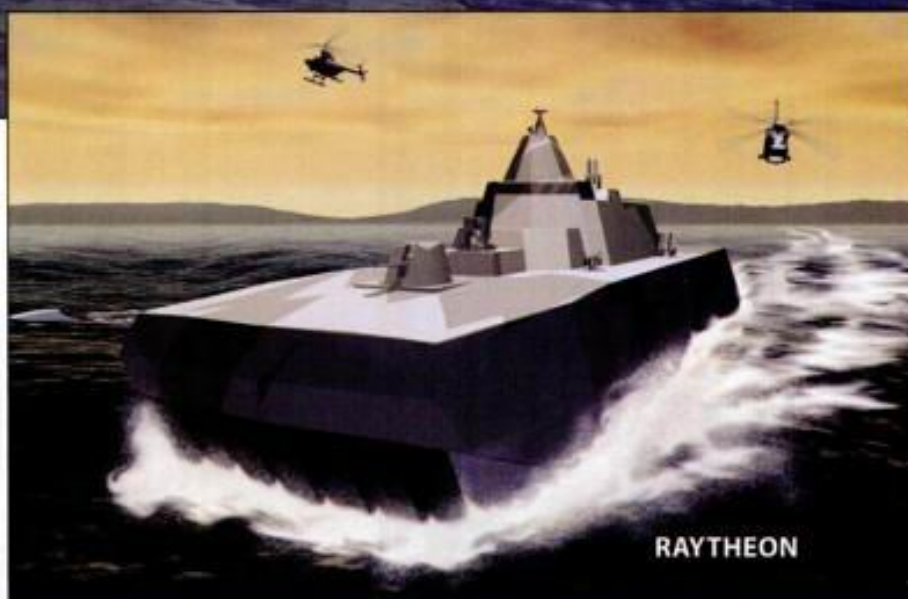


**GENERAL DYNAMICS-
BATH IRON WORKS**

The competition is now between three different hull designs, all of which are fast and stealthy.

aircraft industry. That is, they want the LCS to be a seagoing platform with weapons viewed as plug-and-play accessories. Many of the weapons that the LCS will carry, including Unmanned Aerial Vehicles (UAVs), are themselves only now in development. That sort of flexibility means that an LCS can be configured to operate across a spectrum of military operations, from delivering emergency aid after an earthquake to depositing special forces to trouble spots.

Controlling the flow of illegal arms shipments is yet another mission envisioned for the LCS. NWDC planners sketched this scenario: A 6-ship LCS squadron is under way to investigate possible violation of a United Nations sanction on a rogue nation. Maritime interception has been ordered to investigate suspected arms shipments by a merchant vessel. Two UAVs are launched from an LCS 200 miles from the suspect vessel. One UAV deploys several smaller, autonomous UAVs that monitor communications. Over the radio, the remarks made by the captain



RAYTHEON

of the suspect merchant ship do not coincide with his course tracked by radar. The UAV drops in for a closer look and then transmits images of unusual topside activity. Analysis of this video, conducted thousands of miles away in a Pentagon war room, determines that the crew is preparing to dump the weapons overboard. Three LCSs set an intercept course. A short time later, the merchant crew begins firing rifles at the UAV, which, despite taking evasive action, is hit. Two of the three dispatched LCSs coordinate a boarding operation and capture the weapons. The third LCS provides area defense.

For More Science Features

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In a sense, the LCS would be a Swiss Army Knife of a warship, one that would operate in groups in near-shore waters after first crossing 3500 miles of ocean.

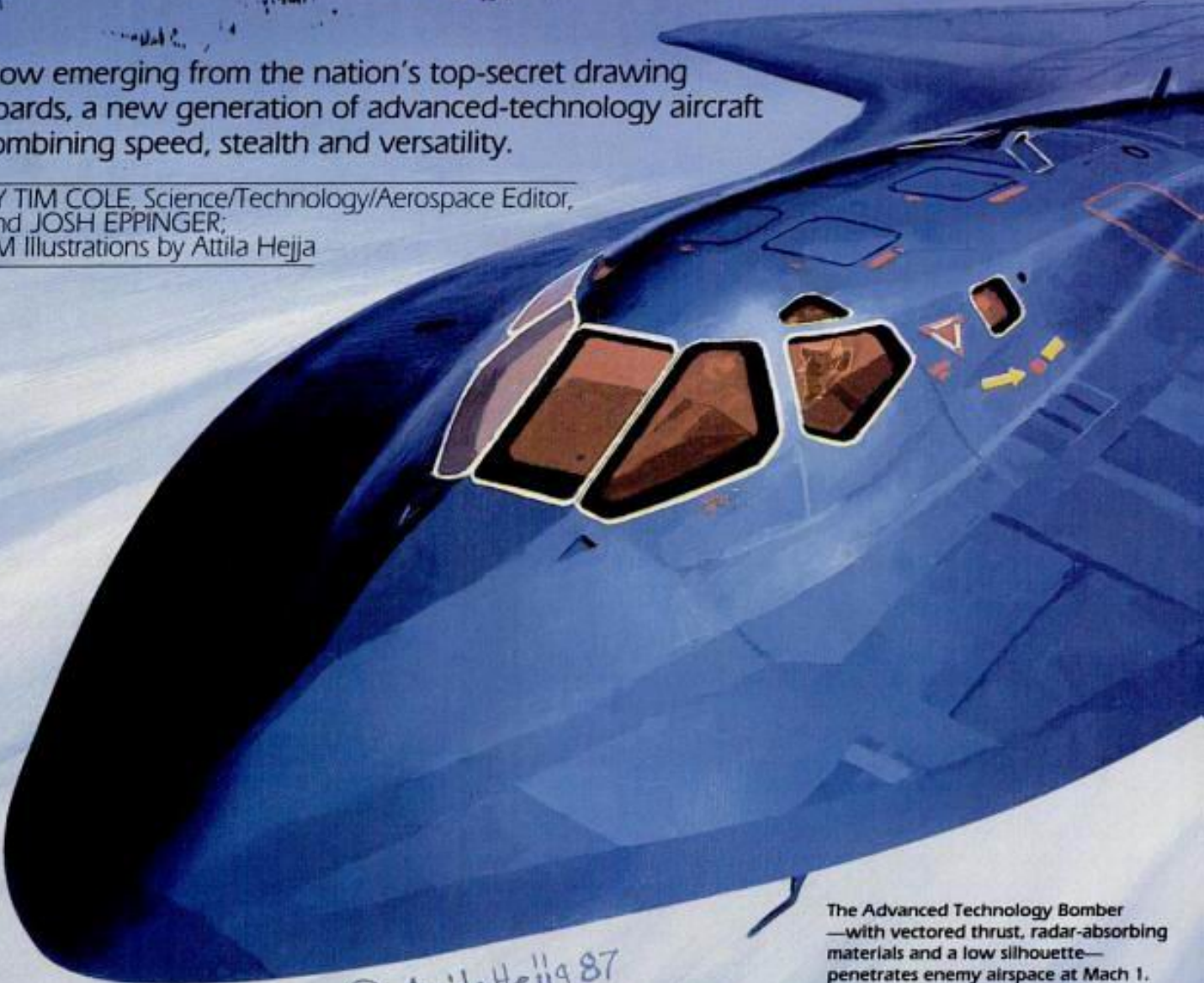
Selecting A Design

This past summer, the Pentagon took the important first step in making those sorts of globally coordinated low-intensity maritime battles a reality. It announced it had selected three contractors to each perform a 7-month preliminary design effort to refine the Navy's LCS concepts. The winners were General Dynamics-Bath Iron Works of Bath, Maine; Lockheed Martin Naval Electronics & Surveillance Systems-Surface Systems of Washington, D.C.; and Raytheon-

AIR POWER

Now emerging from the nation's top-secret drawing boards, a new generation of advanced-technology aircraft combining speed, stealth and versatility.

BY TIM COLE, Science/Technology/Aerospace Editor,
and JOSH EPPINGER;
PM Illustrations by Attila Hejja



The Advanced Technology Bomber
—with vectored thrust, radar-absorbing
materials and a low silhouette—
penetrates enemy airspace at Mach 1.

© Attila Hejja '87

FAST. Low. Virtually invisible.
Deadly.

The words describe the Advanced Technology Bomber, a crucial leg in America's nuclear triad that will join the Strategic Air Command in the mid-1990s. Incorporating "low-observable" stealth technologies, fly-by-wire controls and an astonishing array of electronic countermeasures, ATB also represents the pinnacle of aviation achievement as the turbulent 20th

century draws to a close. Similar technologies designed for light weight, high strength, increased range and payload, accuracy, survivability and maintainability are finding their way into a broad range of currently emerging aircraft. The latest developments include YF-22A, the Advanced Tactical Fighter and an entire family of advanced rotorcraft. The V-22 Osprey, scheduled to take flight in 1991, will be the military's airborne workhorse. Other high-tech

VERTOLs on the drawing board include LHX, the next generation light scout attack helicopter, designed to counter a rapidly expanding East Bloc armor threat; and X-Wing, the rotorcraft that will fly "map-of-the-Earth" at 30 knots to support ground forces, then accelerate to high subsonic speeds to engage enemy fighters.

Each is designed to perform a highly specific function on tomorrow's battlefields. They represent enormous prob-

2000



lems—and amazing possibilities—in the dynamic world of aviation technology.

Advanced Technology Bomber

We begin with the biggest—and clearly most secret—airplane construction project in American history. To fulfill the Air Force's requirement for a "long-range bomber that incorporates low-observable technologies," Northrop Corp. was awarded a \$36.6 billion contract (in 1981 dollars) to produce 132 Advanced Technology Bombers. These will complement the 100 Rockwell International B-1B bombers currently joining the Strategic Air Command.

Preliminary visions of ATB focused on Northrop's post-WWII YB-49 flying wing, an airframe that lacked severe surface angles and was thus considered difficult to track with radar. However, known control difficulties with flying wings—and a thickened, drag-inducing wing cross-section to accommodate payload—has most likely eliminated the concept from consideration.

Instead, numerous industry experts interviewed by POPULAR MECHANICS foresee a large conventional aircraft with a small cross-section in profile and nose-on. A blended shape between the fuselage and the slightly down-sloping wings will eliminate the hard intersections that bounce radar signals. A smooth, hard "chine" will flow from the forward wing-fuselage intersection

around the nose of the aircraft to provide additional nonintrusive sculpting, much like the shape of the forward fuselage of the SR-71 "Blackbird," America's high-flying reconnaissance plane.

Thrust vectoring through 2-dimensional exhaust nozzles will play a major role in control and stability, eliminating the highly observable vertical control surfaces in the tail. A refrigerant will be pumped through the exhaust outlets to reduce the aircraft's thermal signature. Positioning the engines—most likely improved versions of the General Electric F-101 currently serving in the B-1B—deep inside the airframe will further limit thermal detection. Early speculation placed the ATB's four engine inlets—hard, angular surfaces that are difficult to mask from radar—on top of the fuselage.

However, it's felt that placing inlets anywhere but on the bottom of the airplane will lead to air starvation at high pitch angles and during tight terrain-following maneuvers. Accordingly, air intakes will be placed on the underside of the fuselage. But they will open and close through a variable geometry system. High-speed flight will force more air into the intakes, thus requiring a smaller, less visible, aperture. The aperture will increase in size during slower flight over friendly territory.

The resulting shape of ATB will have a radar cross-section one-half that of the B-1B, which in turn has a radar cross-section $\frac{1}{100}$ th that of the aging B-52. And like the B-1B, ATB's objective will be to fly at high subsonic speeds under an enemy's radar and fighter umbrella to strike targets with extreme accuracy. A chief bombing objective might be rail-based ICBMs that change their launch position frequently. Satellites will detect the movement of these mis-

siles and transmit their locations to the national command authority, which will send coded target information to the ATB enroute. The ATB crew can change their flight plan or return to base if requested to stand down—a flexible response not afforded by cruise or intercontinental ballistic missiles.

To carry out its mission, it's conceivable the Air Force will reduce the ATB's flight crew to three from the B-1B's current four. A pilot/copilot will manage the flight from the forward cockpit. An offensive/defensive weapons systems officer will monitor enemy threats, jam enemy sensors, release expendable countermeasures in the form of chaff or flares and drop ordnance. The copilot and weapons systems officer would share some of the work of delivering the load in this scenario.

With an ultralow radar cross-section, the Air Force could afford to create a larger aircraft capable of carrying up to 125,000 pounds of ordnance in multiple stores bays internally. The B-1B currently holds 75,000 pounds inside, and a potential for 50,000 pounds of cruise missiles or other weapons on external hardpoints. The payloads are awesome compared to the 4000-pound bomb loads carried by the B-17. Fewer crew and a correspondingly smaller crew compartment will mean more room for electronic countermeasures, actual weapons and fuel. Unrefueled range will increase well beyond the B-1B's current 6100 nautical miles—a 15-percent increase to 8580 nautical miles has been discussed. Bomb loads will consist of a follow-on generation of the Mark 82 gravity bomb, short-range attack missile, long-range advanced cruise missile, and, potentially, antiradiation cruise missiles that can knock out enemy targeting installations in advance of a strike.

Key features of ATB will be the latest



advancements in radar absorbing materials (RAM) that absorb microwave energy; materials like high-tensile-strength reinforced carbon-carbon, thermoplastics and ferromagnetics. The paint surface, too, will be of a radar-ablative substance. Pyramid- or cone-shaped shells lined with ferrites and positioned just under the leading edge of the wings and fuselage will capture and absorb radar energy.

In short, the ATF fleet will be a potent and formidable component in America's nuclear arsenal. While optimistic progress reports continue to emanate from Northrop Corp., it's highly doubtful the Air Force will be able to conduct the first flight of ATF in late 1987 as originally scheduled. A flying proof-of-concept aircraft in late '88 or early '89 is more realistic, according to Air Force insiders.

The Advanced Tactical Fighter

The Air Force colonel is like John Madden diagramming a delayed draw.

"The Soviets have been gradually increasing their fighter force with a look-down, shoot-down capability," he explains. "So in response to this threat, I need an aircraft to cross over and take them on, to engage them. Therein lies the requirement for the Advanced Tactical Fighter."

The speaker is Col. James Fain Jr., director of the Advanced Tactical Fighter (ATF) system at Wright-Patterson Air Force Base outside Dayton,

ATF will include a smart cockpit, "low-observable" technology and canard-induced "super-maneuverability." A proposed 3-D threat indicator "floats" in an ATF concept cockpit (below).



Ohio. "If we don't respond to the threat, we lose the capability to conduct air combat maneuvers. In short, we lose air superiority. And that's the thing we can't tolerate. We've learned that in war after war. We must have air superiority or we don't have a chance."

Northrop, partnered with McDonnell Douglas, and Lockheed, its Los Angeles-area rival, teamed up with Boeing and General Dynamics, are currently going nose to nose to develop two prototype ATFs over the next 41 months. The contracts are worth \$691 million each, and defense industry executives are calling it "one of the bloodiest competitions in the history of the aircraft business." The winner will waltz away with a production contract that calls for 72 aircraft a year, at least to the year 2005, or until 750 of the ATF's roll to the

chocks at U.S. Air Force Tactical Fighter Wings around the world.

In awarding the two contracts, Air Force Secretary Edward Aldridge says the new offensive fighters will be needed to counter two Soviet supersonic, all-weather fighters—the MiG-29 Fulcrum and SU-27 Flanker. Both Soviet planes are twin-engine, high-performance machines with improved range, thrust-to-weight and maneuverability. They can carry powerful long-range radars and radar-guided missiles for both dogfights and for beyond visual range, with look-down, shoot-down capability.

Also locked in heated competition are Pratt & Whitney and General Electric for the propulsion that will power this aircraft. They were awarded contracts in 1983 to develop the prototype ATF engines and are rushing to build an engine that satisfies the Air Force's thrust-to-weight ratio of 1.2:1 or better. That means if the aircraft weighs about 50,000 pounds, 60,000 pounds of thrust is required.

Although many of the details of the ATF are cloaked in a black shroud of security, Gen. Lawrence Skantze, commander of the Air force systems command, dropped more than a few hints in a speech last year. He said, "The ATF will leave the transonic flight era behind and thrust us into the age of sustained supersonic combat."

"The cues an adversary will use to try to hunt it down—like infrared, visual radar signatures—will be reduced with low observables technology. Stealth



Slats in X-Wing's rotor will create lift in transition from vertical to horizontal flight. Plane will fly low-level attack, and engage fighters.

will also reduce vulnerability to ground-to-air missiles.

"An integrated electronic warfare system will reinforce the ability to penetrate enemy airspace undetected. An avionics architecture called Pave Pillar will fuse masses of sensor information for a totally integrated avionics suite. With VHSIC (Very-High-Speed Integrated Circuits) we'll require only about $\frac{1}{11}$ th as many integrated circuits as presently used in aircraft electronics. That means far fewer cables and connections, for fewer failures at a fraction of the cost.

"The fighter will aid the pilot in making split-second decisions using artificial intelligence and other technologies like helmet-mounted displays and sights. The Air Force is working on computer voice-recognition and advanced control and displays so the pilot will be able to communicate with his aircraft, and ask for particular displays of data to be superimposed over his visor."

The general is referring to a "pilot's associate," a combination of advanced computerized systems, crammed with artificial intelligence that will help the pilot survive. It will feed the pilot, in simple graphic form, information relative to his own aircraft, mission planning, the enemy's attack, tactics to utilize and communication with aircraft subsystems. The computer systems will have speed, visual and tactile modes. They will utilize infrared, laser and radar sensors in a target recognizer that "looks" at an object—even from a long distance, creates a computerized model from memory of what it thinks the sensors are "seeing" and then compares data from the sensors against the model to determine what the object really is. The single pilot will not be bogged down with an onslaught of numbers and letters. Instead, he will be presented with full-color, programmable, pictorial formats for real-time decision-level systems and mission information. Boeing is even studying the feasibility of incorporating a third dimension to the images pilots will see on pictorial displays. The

single pilot of the ATF will thus be able to concentrate on his number one priority—the mission at hand.

At \$35 million each, the ATF will be the most expensive fighter plane ever to take to the air. It will be able to cruise supersonically at 1.5 times the speed of sound or 1300 mph. It is expected to double the combat radius—out to 1000 miles from its base and return—as well as fly twice as many combat missions in a given period of time. It will also have triple the engine reliability of the current F-15 Air Force fighter, designed in 1969. To create a plane with both range and speed, the ATF is being forged from new materials. Plastics may have been the cry of an earlier generation. Today it is thermoplastics. From 40 to 60 percent of the ATF's structural weight will consist of thermoplastic matrix composites. This will enable the aircraft to fly with the same payload and range at half the empty weight of existing fighters. This should make the ATF 20,000 pounds lighter than fighters built from conventional metal alloys.

Dr. Gary Denman, director of the materials laboratory at Wright-Patterson, explains the use of thermoplastics. "It's kind of like Tupperware," he says. "It's tough and if you ever put it on the stove, you'll know it melts. It's easy to form. But chemical companies are looking hard at ways to improve the temperature capability of thermoplastic materials and I imagine most of the ATF will be made up of them."

To maximize lift and minimize drag for fuel-efficient cruising in the ATF, variable camber wings will automatically change their curvature in flight. Preliminary testing with mission adaptive wings (MAW) on an F-111 operated in a manual mode are coming close to goals of range increases of up to 25 percent for typical supersonic, low-altitude missions and up to 30 percent for normal high-altitude missions.

There are no conventional flaps, slats, ailerons or spoilers on the MAW-equipped F-111. Instead, a composite skin covers flexible leading and trailing edges whose shape is continuously and



Lightness, strength, agility and advanced electronics define LHX. Top speed: 170 knots.

AIR POWER 2000

automatically adjusted by a digital flight control system.

Less is known about the Navy's version of the advanced fighter, the ATA. The Navy has imposed a black security net over the aircraft, but aviation experts reason that the ATA's needs will still be tied to the large-deck aircraft carrier.

The New Rotorcraft

Igor Sikorsky would be aghast. The pioneer of vertical flight would never have imagined that his creation—the helicopter—would one day mesh with such a variety of VERTOLs able to fly at high subsonic speeds. That day is now. Rotary-wing technology is lifting off from the drafting tables at accelerating speeds, with a variety of configurations serving a number of missions. PM looks at the latest creations: the X-Wing, the LHX and the V-22 Osprey.

The X-Wing

The X-Wing, currently undergoing its first tests at NASA's Dryden Flight Test Center at Edwards Air Force Base in California, is an aircraft that takes off and lands vertically, hovers with helicopter-like efficiency and control, then flies at high subsonic speeds. Developed by Sikorsky, the X-Wing is the first aircraft to use a lift and control system to transform its large-diameter rotor into an efficient fixed wing.

What makes all this possible is something called the Coanda Effect—streams of air forced over a curved aerodynamic surface will follow the contour of that surface, entrain the surrounding air, and provide lift. Thus, in some 30 seconds when the rotor is stopped to become a fixed wing, pressurized air is blown through slots along

the 27-ft. length of the blades, producing both aircraft control and lift.

The X-Wing, which is first being tested on a vehicle known as the Rotor Systems Research Aircraft (RSRA) to demonstrate that it indeed can convert from rotor to fixed wing in flight, incorporates pioneering applications of composites, computer and circulation-control aerodynamics. "Here you have something that could fly map-of-the-Earth at some 30 to 40 knots when that was appropriate, go out and do helicopter dogfights and then also fly at 450 to 500 knots and do dogfights with fixed-wing airplanes," says Arthur Linden, engineering manager of Sikorsky's X-Wing project. The X-Wing will also be elemental in improving protection for Navy fleets by flying long-range patrols from small ships sailing well in advance of the main fleet. Once in position, it can then hover for sonar dipping or search and rescue missions.

The LHX

To counter the effectiveness of the Soviet Mi-24 "Hind" helicopter and replace an aging fleet of light helicopters, the Army is developing an agile, high-speed advanced family of rotorcraft in the 8000-pound class. Designed by Boeing Vertol Co. and United Technology's Sikorsky Aircraft, the LHX will field two models of a lightweight, low-cost helicopter—a scout attack version, and a utility version.

The LHX will be powered by twin 1270-shaft-horsepower engines with a top speed of 170 knots and the ability to climb at 500 ft. per minute. It will incorporate very-high-speed integrated circuits, a fiberoptic control system and advanced composites, structures and aerodynamics. One aim of the LHX aircraft is to reduce weight. Thus, composites will be a prime component of the

LHX. One version, known as SCAT, might be flown by just one pilot—assisted by a highly complex system of computer-aided avionics. The pilot will primarily focus on flying with essential flight and weapons information projected on his helmet visor. Systems will be activated by voice commands and it is conceivable the system will be able to talk back to the pilot.

The LHX will be piloted by means of a short, videogame-like stick mounted on the right armrest. The LHX's main core could consist of sensors, processors, displays and controls that will handle navigation, targeting, fire control, flight control, fault detection and other equipment—a stiff technological challenge.

The V-22 Osprey

The V-22 is a tilt-rotor aircraft combining a modern turboprop plane with the vertical take-off and landing capabilities of a conventional helicopter. It will

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Carefully tear along perforation to remove.

cruise at 275 knots and carry combat payloads more than 1000 nautical miles. The joint Bell Helicopter Textron/Boeing Helicopter design currently moving toward production will use forward-swept-wing technology and advanced composites. It will have great utility for all the armed services: The Marine Corps sees it as a medium assault transport; the Navy for combat search and rescue, special warfare, fleet logistics and antisubmarine warfare; the Air Force for long-range insertion and extraction of special operations forces; and the Army for aeromedical evacuation, combat transport of troops and supplies and other support functions.

Bell Helicopter Textron, Inc., and Boeing Vertol Co., the tilt-rotor team, like to boast of the Osprey's potential: twice as fast as a helicopter, twice the range, can carry a comparable payload twice as far and twice as fast as today's helicopter, increased survivability and reliability, plus easier maintainability.

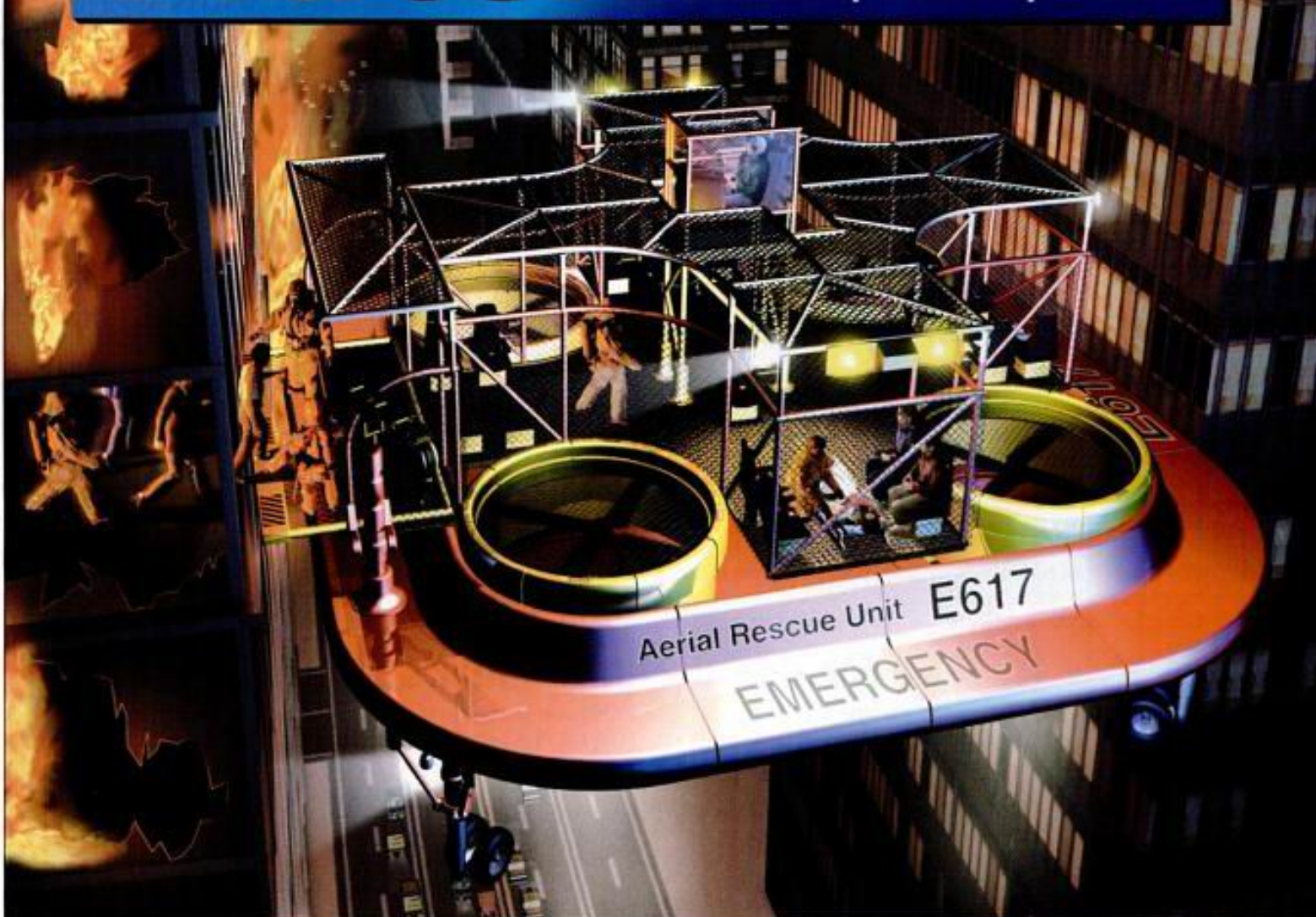
The V-22 will be the earliest advanced technology aircraft to enter the four services, with a first flight scheduled for 1991. But its impact will be felt far into the next century. Consider the venerable C-130. Designed in the early '50s, it's still ferrying troops and equipment. Likewise, today's concepts for ATB, ATF, X-Wing and LHX will be flying at least until 2025. More than advanced aircraft, today's aviation concepts thus become our legacy of flight. **PM**

The V-22 Osprey will take off like a helicopter and fly like a plane using tilting engines. A cross-link system operates both blades on one engine if one powerplant fails.



Technology Watch

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Rescue Platform Rides On Air

The Eagle flying platform could be the next piece of must-have hardware for big-city fire departments and rescue squads.

Made of lightweight graphite epoxy and powered by four small aircraft engines, it can climb higher than the reach of the tallest ladder, navigate narrow streets,

and work near powerlines and other places too dangerous for helicopter rescue baskets.

The Eagle rises on jets of air created by ducted fans. Pitch, roll and yaw are controlled by adjusting

the angle of the fans. To protect against engine failure, the fans are cross connected. Developer David Metreveli says the platform will be able to safely land with only two of its engines running. With all four operating, the Eagle can rescue as many as 10 people at a time.

Metreveli says that his company, DM AeroSafe Group of Ashdod, Israel, has tested an electric-powered proof-of-concept model and plans to begin work on a flying prototype and smaller platforms operated by remote.



August Highlights

Better Blastoffs—NASA counts down to the launch of a new space shuttle engine.

■ **Hands-On Learning**—Mechanics practice repairs on computers that have a sense of touch.

■ **Sweden's Plastic Corvette**—An inside look at a fast, deadly and nearly invisible warship.

Editor: Jim Wilson
Reporters: Dennis Blank,
Louis Brill, Stefano Coledan,
Sarah Deem, Mike Filon,
Scott Gourley, Claude Morgan.



The Soviet theory of air superiority has stood the test of 40 years.

by Murray Rubenstein

MiG:

The ultimate airplane killer

Throughout the annals of what we have come to know either as the Cold War or Detente, depending on whether there is a crisis or lack of one, perhaps no other one-word label has become so immediately associated with a sense of threat as has the term MiG. In fact, as a worldwide household word, it may even rival Coca-Cola. Why the products of one aeronautical design "bureau" within the Soviet Air Ministry have achieved this kind of brand-name notoriety (or fame, if you happen to be a pilot in the Libyan, Cambodian, Cuban, Ethiopian, Iraqi or any of a dozen other nations' air forces) is something worth pondering.

It is also an ongoing phenomenon that is currently responsible for the sleepless nights of Western military strategists who must deal, at least hypothetically, with its latest manifestation—the MiG 29 (painting at right).

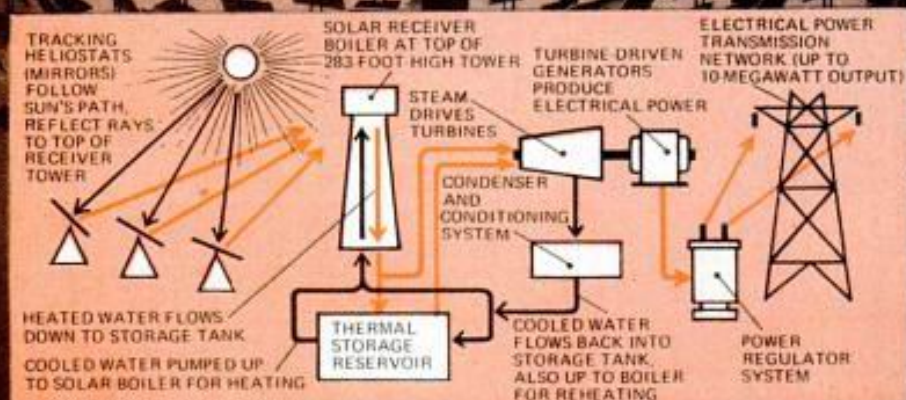


PM art: Ed Valigursky

This artist's conception of the MiG 29, still shrouded in secrecy, is based on details from authoritative sources concerning its new radar, engines and armament.



Acres of mirrors surround 283-foot-tall tower in artist's concept at left, depicting what will be world's largest solar furnace when completed in the desert wilderness near Barstow, Calif. Pivoting mirrors, called heliostats, automatically track sun, focusing rays on giant boiler atop tower. Diagram shows how concentrated heat on boiler turns water into steam, driving turbo-generators to produce electrical power—up to 10 megawatts, enough to run a city of 10,000. Photo above shows pilot plant at Sandia Laboratories near Albuquerque, N.M., where components for future solar furnace are being tested.



HOW SOLAR MIRRORS LIGHT UP A CITY

Bold new look at a bright new sun

New schemes to harness solar energy on a large powerplant scale now appear more promising. Here's how acres of mirrors might energize a city.

by Mort Schultz

Shades of Akhnaton," I thought. They've built a blooming sun temple right here on American soil."

There before me, sprawling out over 100 acres of New Mexico desert near Albuquerque, was an enormous field of some 300 giant, shimmering mirrors all aimed toward the sun. Rising from their midst was a 200-foot-tall tower, looking much like a king surveying his subjects. Solar rays caught and reflected by the mirrors were focused on a pinpoint spot near the tower's top. The desert glowed in a blaze of light.

The effect was eerie. As the sun tracked across the sky, the mirrors turned slowly in unison to follow it, like worshipful robots, always keeping their reflected light beams shining precisely at the tower.

And what was atop that awesome tower? No—not a solid gold idol like that which adorned King Akhnaton's temple to the sun god more than 3000 years ago in ancient Egypt. There, looking out upon its "kingdom," was a boiler—an ordinary steam boiler filled with water.

What prompts modern man to build a sun temple to a boiler? Why spend \$21 million in tax dollars to cultivate a monstrous crop of glass?

The answer is simple: power. The idea behind this huge "solar farm," built by New Mexico's Sandia Laboratories, is to use intense solar heat to create steam that, in turn, drives turbogenerators to produce electricity. Many scientists have concluded that solar energy, to be really practical, must be "harvested" in

massive amounts and converted into electricity at large, central powerplants that would supply entire communities, just as conventional powerplants now do. Small, individual solar collectors of the type now being installed on many residential homes are fine for providing supplemental heat or power, especially in mild, sunny climates, but they lack the tremendous capacity needed to light a city, run a factory or drive a train. In other words, say experts, when you think solar, think big.

No solar shortage

Actually there is no shortage of solar energy. It has been estimated that sunlight falling on the earth in a single day, if converted into usable forms, could satisfy the power needs of the whole world for a year. But sunlight is not concentrated, does not fall in all areas at the same time, and does not always shine when you want it to.

With fossil fuels dwindling fast, the energy shortage has become so critical that the U.S. Department of Energy has established an extensive program to develop a means for harnessing sunpower on a large scale. Involved are four industrial research giants—Boeing, Honeywell, McDonnell Douglas Astronautics and Martin Marietta Aerospace. Sandia Laboratories acts as a testing and advisory facility.

At Sandia, the purpose of that gigantic field of mirrors is to capture scattered light rays and concentrate them into a beam so sharply focused and intensely hot that temperatures in the steam-producing boiler can reach 1000° F. The principle is similar to the old trick of using a magnifying glass to burn a hole in paper—the lens focuses normal solar rays to a point where they can start a fire. (This is why you should never look directly at the sun through a camera lens, binoculars, telescope or other optical instrument—the concentrated sunlight could blind you.)

Automated mirrors

The self-moving mirrors, called heliostats, are swivel-mounted, motor-driven and computer-controlled so they follow the path of the sun automatically at the exact angle to keep reflected rays beamed constantly at the boiler throughout the duration of daylight. Each heliostat consists of 25 4-foot-square silver-plated, laminated-glass mirrors, totaling 7500 individual pieces of glass. The rated electrical output of such a system is 6.5 megawatts—impressive now, but modest compared with what's to come.

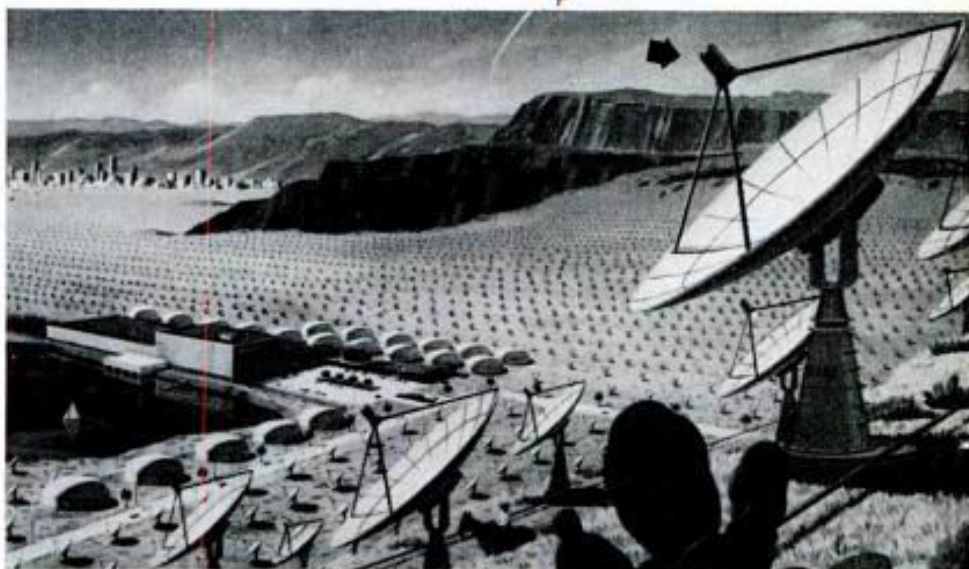
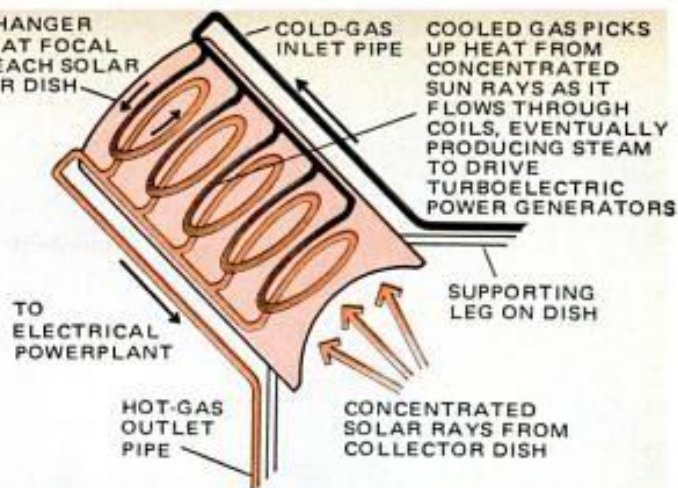
Small by comparison

As extensive as it is, the Sandia operation is actually a relatively small pilot plant designed to test components for use in much bigger installations. It will be dwarfed by a 10-megawatt colossus already sprouting in desert wilderness near Barstow, Calif. This installation will employ more than 1500 heliostats surrounding a 283-foot-high tower. Each heliostat, if it follows the Sandia design, will be 20 feet square and contain 25 separate mirrors for a total of 37,000 reflectors all aiming reflected solar rays at an immense boiler atop the tower. As in the Sandia system, the blistering concentrated heat will turn water into high-pressure, superheated steam to drive powerful electricity-producing generators. Cooled water is fed up the tower to the boiler and the solar-sizzled steam piped down to giant turbogenerators.

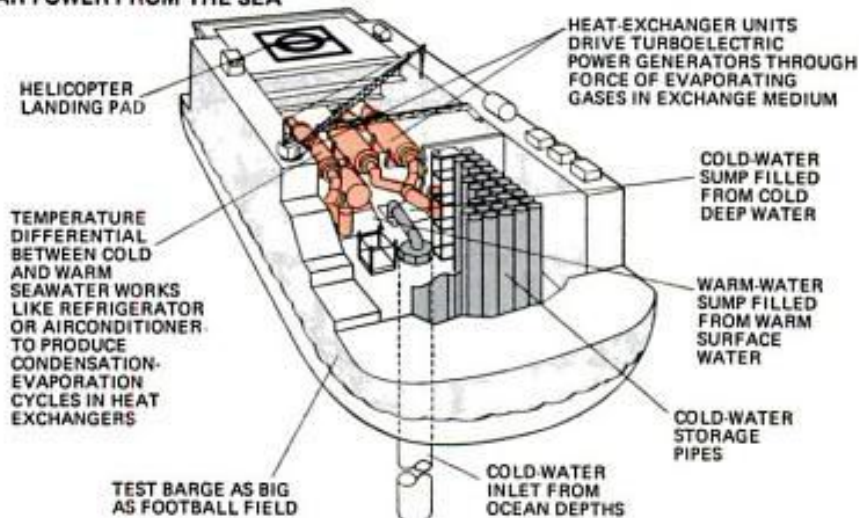
At night or on sunless days, excess heat retained in a thermal storage system will be sufficient to keep the generators running up to about six hours in present designs. Beyond that, conventionally fired backup furnaces will kick in to bridge the gap until the sun shines again. The 10-megawatt output (a megawatt equals a million watts) will supply enough power to serve a community of 10,000 inhabitants.

When the Barstow plant is com-

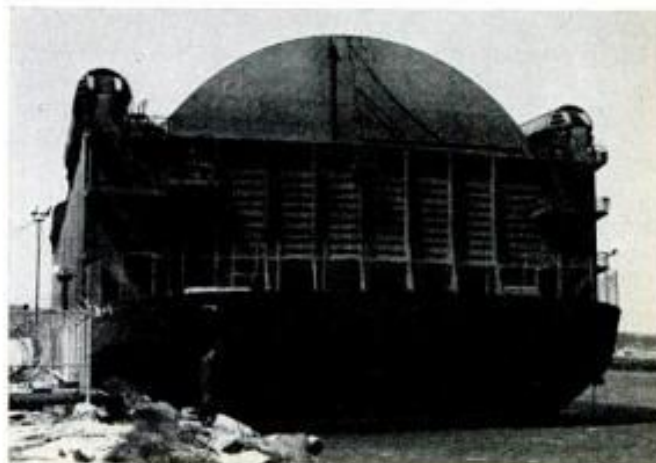
Solchem scheme (for "solar chemistry") is similar to sun furnace on facing page. It, too, uses solar collectors but has no boiler tower. Each collector aims sun rays at coil mounted at its focal point (arrow below, drawing at right). Complex system basically heats gases to run steam-driven generators through exchangers.

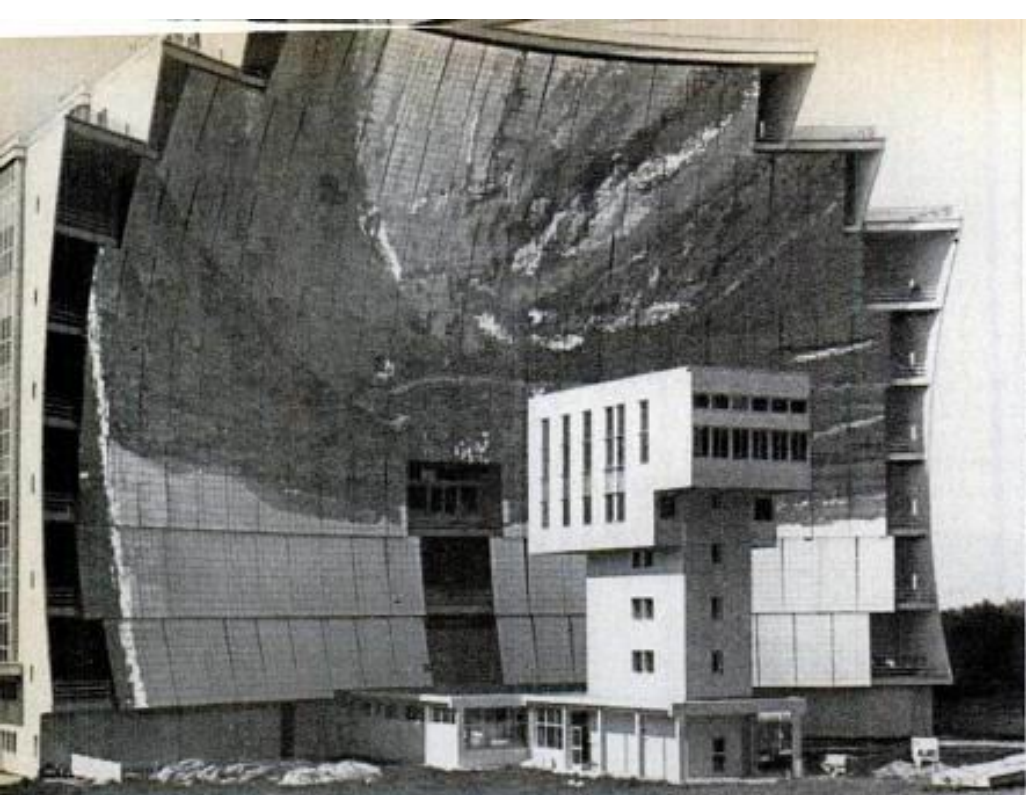


SOLAR POWER FROM THE SEA

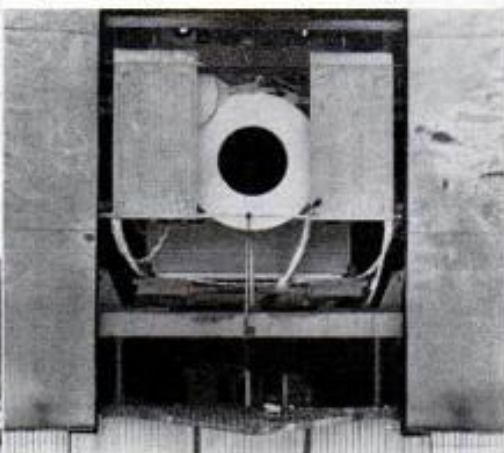


Giant barge will go into operation next year to test new method of extracting solar energy from seawater, called "ocean thermal energy conversion" (OTEC). System works on temperature differential between warm surface water and cold deep water—up to 45° F. Warm water heats fluid in coils, producing high-pressure gases to drive electric generators. Cold water condenses gases and the cycle repeats.

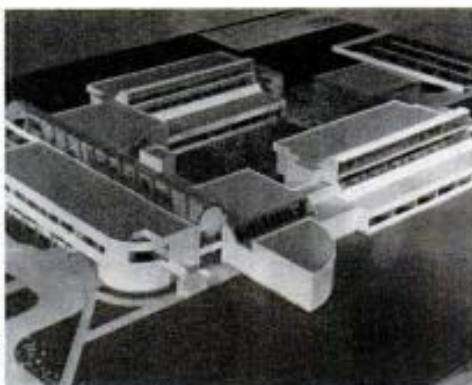




World's largest mirror is 10-story-high parabolic reflector atop Pyrenees Mountains in southern France. Not seen in foreground are sun-tracking solar collectors that aim sunlight at huge reflector. Reflector then concentrates sun's energy on boiler in small building in front of it. Photo below shows pinpoint hole into which energy is beamed to heat boiler, producing steam for power generators.



Already in operation, the nation's largest solar heating and cooling system is currently in use at the George A. Towns Elementary School in Atlanta, Ga. Over 50 A-shaped rooftop solar collectors supply more than 60 percent of the school's heating and cooling needs. Reflectors on back slope of each unit allow collectors to absorb energy from both direct and reflected sunlight for maximum efficiency.



Coming soon is new solar-powered facility for Mississippi County Community College in Blytheville, Ark. Shown in model above, it will employ photovoltaic solar cells instead of conventional fluid-type solar collectors. The cells, like those used on spacecraft, convert sun energy directly into electricity—enough to supply MCCC's entire heating, lighting, cooking, airconditioning and other power needs.

pleted in late 1980 or early 1981, it will be the world's largest solar furnace—but not for long. Already being planned are solar powerplants capable of producing 100 to 300 megawatts in as little as 10 years. And vast solar facilities turning out 40,000 megawatts—4000 times the Barstow capacity—are foreseen by the turn of the century.

Big mirror on a mountain

High atop a towering peak in the Pyrenees Mountains near Odeillo in southern France looms a dish-shaped mirror so big its diameter spans the height of a 10-story building. Its use is basically similar to that of the Sandia and Barstow installations except that it involves a two-stage collection-reflection system of capturing solar energy.

Surrounding the mirror is an array of sun-tracking heliostats, but instead of beaming their light rays directly at a boiler, they aim them at the center of the huge mirror. The parabolic mirror, resembling a giant radar antenna, then further intensifies the light rays and concentrates them on a boiler at its optical focal point, also the point of maximum heat buildup. From here on, the power-producing process is that of Sandia's and Barstow's—steam from the sun-heated boiler spins turbine-driven electric generators.

Temperatures reach 7000° F.

Using this method, boiler temperatures of up to 7000° F. can be reached. Some experts, however, argue that, despite the high temperatures generated, there is actual-

ly a loss in solar-conversion efficiency due to the double-reflection arrangement used—something like the loss in fidelity you get when recording a recording or making a copy print from an original photo. (Electrical output from the Odeillo installation is a mere 1 megawatt—puny alongside Sandia's 6.5 and Barstow's 10—though a direct comparison is unfair since the unique mountain-top collector is much smaller.)

In any case, the joint French-American venture, under the direction of the U.S. Department of Energy, is not meant to be a major power producer, but was built to function as an experimental center, like the Sandia plant, for testing components for use in future solar projects. Nobody argues about the impressive size of that 10-story-high parabolic mirror.

Chemical solar collectors

Still another scheme to harness sunpower in massive amounts has been proposed by scientists at the Naval Research Laboratory in Washington, D.C. Called Solchem for "solar chemistry," it may sound complicated but appears to represent an ingenious use of the chemistry of gases to collect and store solar energy at maximum efficiency.

The system uses sun-tracking solar collectors like heliostats but dish-shaped like the parabolic French mirror. Instead of beaming sunlight at a boiler, they concentrate it on a series of coils mounted on legs at the focal point of each dish. Sulfur trioxide gas (SO_3) enters the coils cold on the intake side, is rapidly heated by the focused sun-

(Please turn to page 134)

About 500 men died for every mile of the 50-mile-long Panama Canal, four-fifths of them under the old French canal company. Yellow fever and malaria were prime causes, but even with disease under control the construction of the canal was a struggle.

Men, steam shovels and dirt trains strained and slipped in the mud and rain at the bottom of the deep trench—the nine-mile Gaillard Cut—through the continental divide. The total excavation was enormous—310 million cubic yards, counting the French effort. The spoil would fill dirt trains encircling the Earth four times at the equator, or build a pyramid seven times higher than the Washington Monument.

More explosive energy than had been used in all the nation's wars up to 1914—the year the canal opened—was needed to blast the cut through high elevations. And time after time thousands of tons of rock and dirt cascaded down onto men and machines as the sides of fractured mountains suddenly and unexpectedly slid into the cut.

Today the Panama Canal is quiet, the din long since gone. From a vantage point on the deck of a freighter, one watches the big lock gates swing open; the peace is disturbed only by the muffled whine of winches as the electric mules haul the ship through. Nothing disturbs the beauty of Gatun Lake. The water laps gently at the edges of the jungle as ships pass. Even Gaillard Cut, scene of many a landslide, has been relatively quiet since 1975.

Ahead of its time

The Panama Canal has served world trade and national defense for nearly 64 years. While its design was far ahead of its time, ship traffic and technology have been catching up, especially in the last two decades.

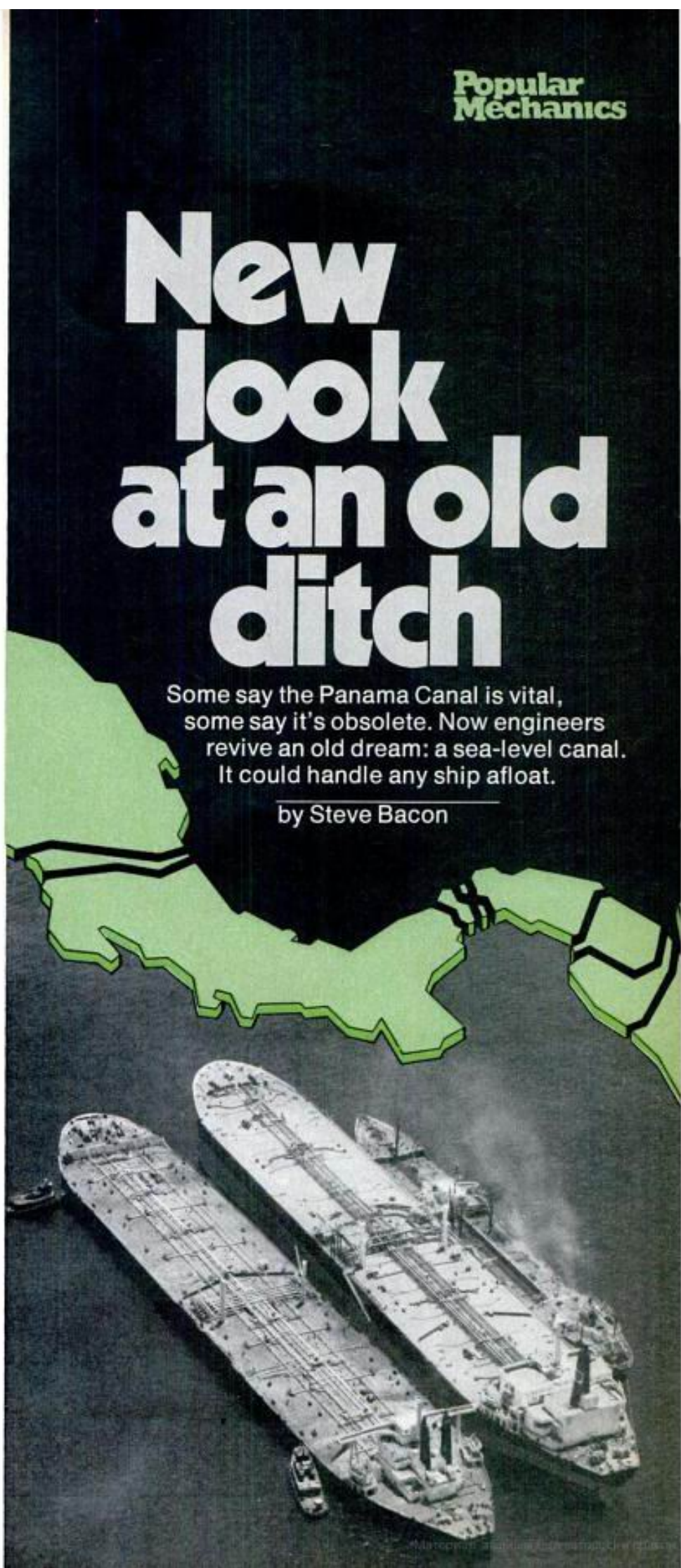
The number of ships using the

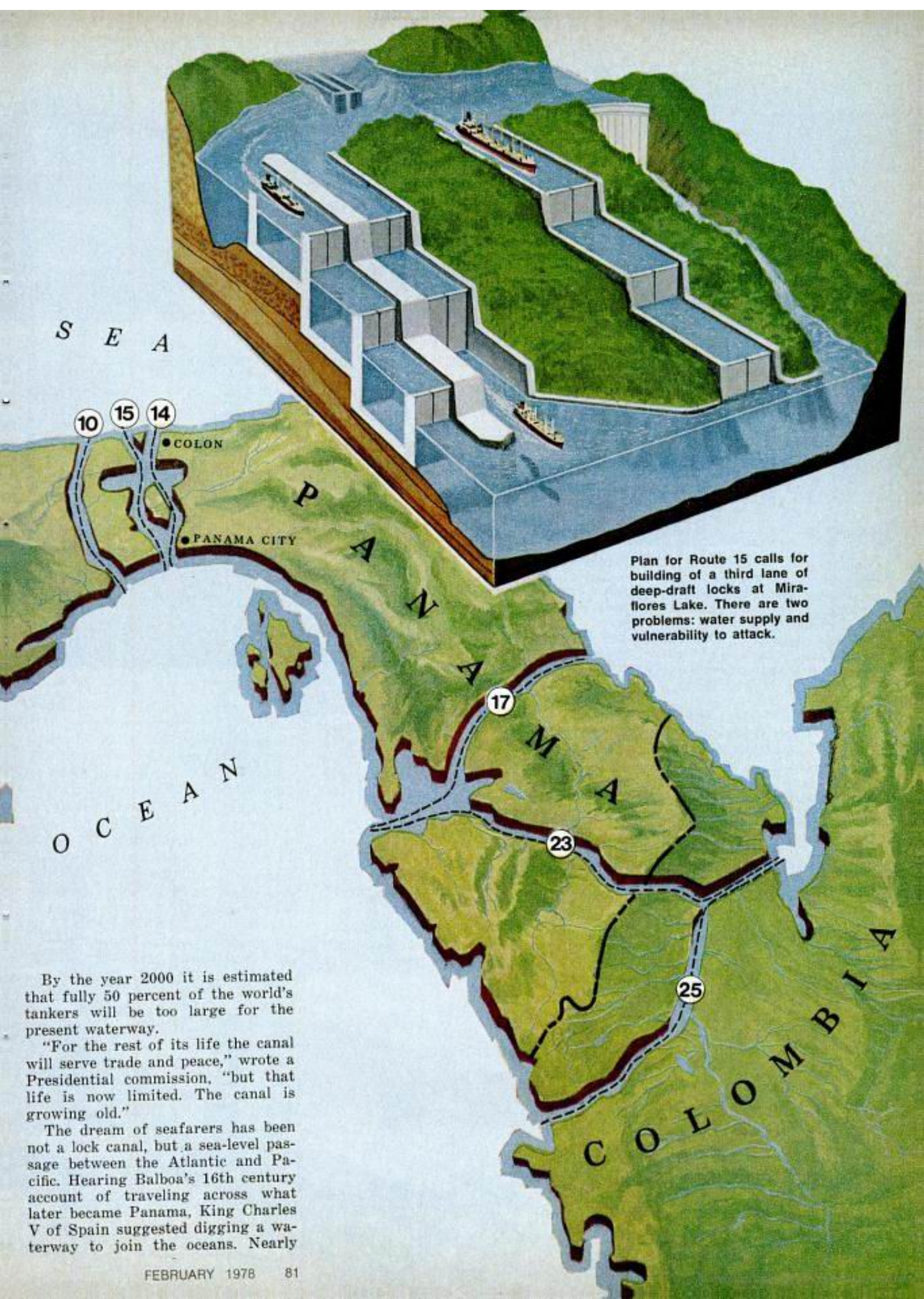
New look at an old ditch

Some say the Panama Canal is vital, some say it's obsolete. Now engineers revive an old dream: a sea-level canal. It could handle any ship afloat.

by Steve Bacon

Supertankered to Panama, Alaskan oil must be pumped to storage tanker (center) for transfer to carriers that fit the canal.





Plan for Route 15 calls for building of a third lane of deep-draft locks at Miraflores Lake. There are two problems: water supply and vulnerability to attack.

By the year 2000 it is estimated that fully 50 percent of the world's tankers will be too large for the present waterway.

"For the rest of its life the canal will serve trade and peace," wrote a Presidential commission, "but that life is now limited. The canal is growing old."

The dream of seafarers has been not a lock canal, but a sea-level passage between the Atlantic and Pacific. Hearing Balboa's 16th century account of traveling across what later became Panama, King Charles V of Spain suggested digging a waterway to join the oceans. Nearly



New mini flattop 'flies' like a plane

Photos: Official U.S. Navy

So stable a cup of coffee won't spill in heavy seas, this fast, twin-hulled ship launches helicopters, fires missiles, may ferry people.

by Larry Wood

Famous racing-boat builder Gar Wood had the idea back in the early days of World War II: Slice a hull in two, stretch a platform across the two halves, and you have a very stable craft capable of high speeds in rough seas. The principle was simple: It's easier standing on two legs than one.

While nothing came of Wood's dream ship in time for use during the war, it did help spur development of a whole new breed of multihulled designs that went on to be the rugged catamarans and trihulls so widely used today in pleasure boats.

Now, some 3½ decades later, the U.S. Navy is applying basically the same principle to a twin-hulled mini aircraft carrier called an SSP for Semi-Submerged Platform. It gets its name from the fact that it is literally semisubmerged—half above the water and half below. The objectives are essentially the same as Gar Wood's: lots of deck space for a given hull length, high speed because of low water drag and uncanny stability in rough seas.

The first SSP to undergo tests is the *Kaimalino*, designed by Dr. Thomas C. Lang, head of the Advanced Concepts Div. Naval Ocean Systems Center in San Diego, Calif. The unique 190-ton vessel, admittedly boxy-looking, is 89 feet long, 46 feet wide at midsection and 32 feet high. Its range is 400 nautical miles at speeds up to 25 knots, while carrying 30-ton payloads and 18.8 tons of fuel. She's a performing beauty.

There has long been a need for small, fast, seagoing naval vessels,

but the problem has always been one of simple physics: The smaller you make a hull, the more sensitive it is to wave motion. While a large ship will plow through heavy seas, a small one wallows in the waves, pitching and rolling to the point where it is useless and dangerous.

A hybrid design

The SSP is aimed at overcoming these drawbacks to small ships. Actually, it is not a true catamaran but more like a cross between a catamaran and hydrofoil craft—with the best features of both. Hydrofoils offer high speed, low drag and good stability in calm waters, but have difficulty operating in heavy seas because of the danger of a foil breaking up through the surface in a wave trough and suddenly losing lift. By contrast, the SSP has four surface-piercing struts, two on each side, that support the above-water superstructure on two long, torpedo-like underwater hulls. The struts are



streamlined to offer minimum resistance. The submerged hulls are carefully ballasted with fuel and water compartments to gain controllable buoyancy, yet keep the craft heavily bottom-weighted for stability. Unlike hydrofoil craft, there is no chance the submerged hulls could accidentally lose lift.

'Flies' like a plane

What makes the SSP even more unusual is its elaborate system of control surfaces that enable it to "fly" through the water much like an airplane in air. Controllable bow planes—called "canard" wings—can be operated either collectively (in the same direction together) or differentially (in opposite directions) to provide delicate trim control at the bow. A horizontal cross-stabilizer connecting the hulls at the stern contains two movable flaps that can also operate collectively or differentially. Used together, they work like an airplane's elevator to control up and down movements. Used differentially—one up, the other down—they act like "ailerons" to help the ship make smooth, banking turns.

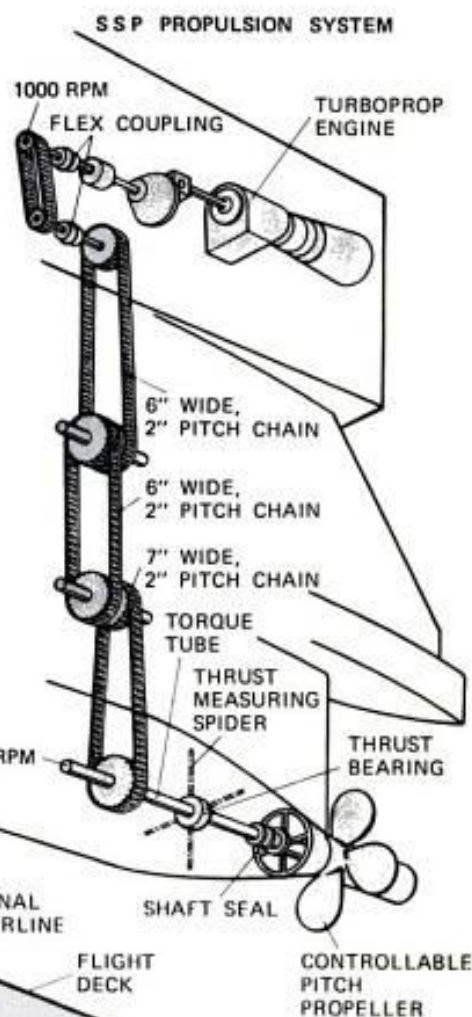
Twin rudders provide directional control at high speed and differential

thrust at low speed, the latter to help in delicate close-in maneuvers. The twin screws can be controlled independently and have variable-pitch and reversible-pitch prop blades. A DC-10 or 747 couldn't ask for better.

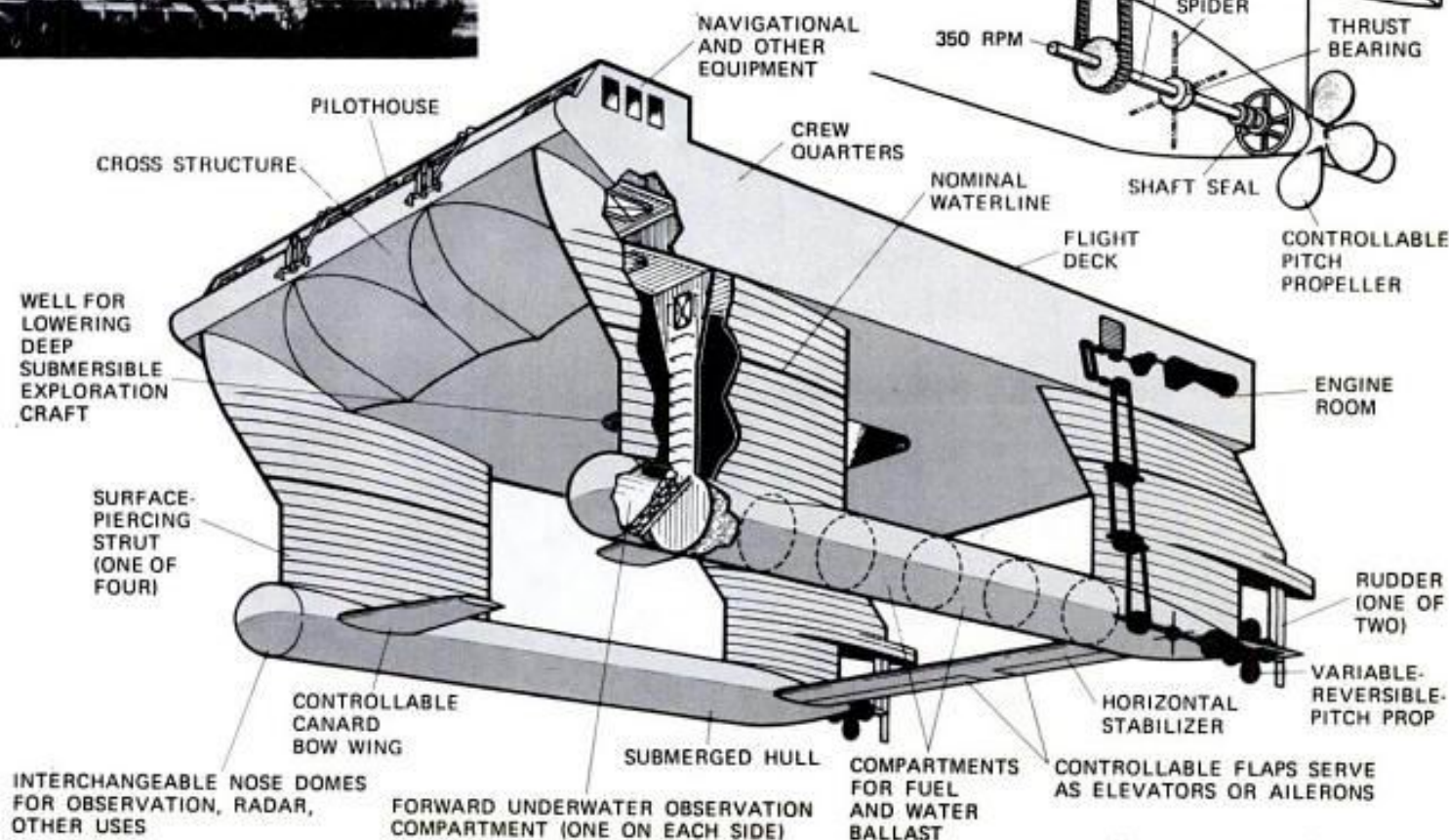
The result is that all of these intricate and ingenious navigational aids give the SSP complete control over pitch, heave, roll and yaw, even in the roughest seas. They can be

(Please turn to page 130)

Unusual four-step reduction drive carries power from turbine engines (one in each hull) to controllable-pitch propellers.



Chasing fast-moving 25-knot SSP platform ship, a Navy SH-2F helicopter (top left) makes a perfect bull's-eye touchdown on flight deck (center), proving SSP's stability even at high speed. At lower left, SSP is small enough to be hoisted aboard a mother ship for overhaul or transport.



1
CHUTIST TRIPS
COMPRESSED-AIR
VALVE WITH
LEFT FOOT

COLLAPSED
LANDING
PAD IS
WORN
ON RIGHT
FOOT



AIR
VALVE

2
LANDING PAD
INFLATES
AS AIR VALVE
IS PRESSED

3
CHUTIST
LANDS
SAFELY
WITH BOTH
FEET ON
PAD TO
CUSHION
IMPACT



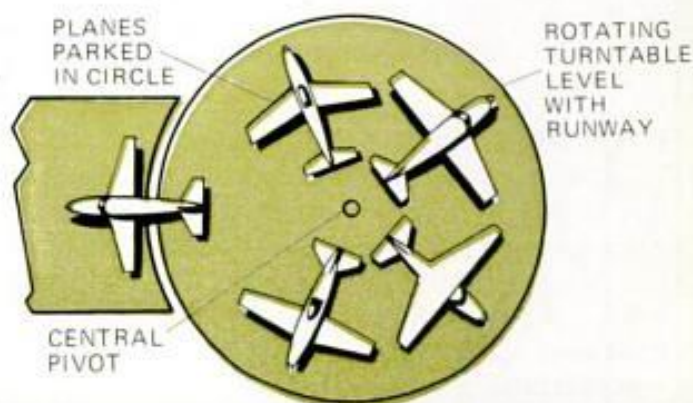
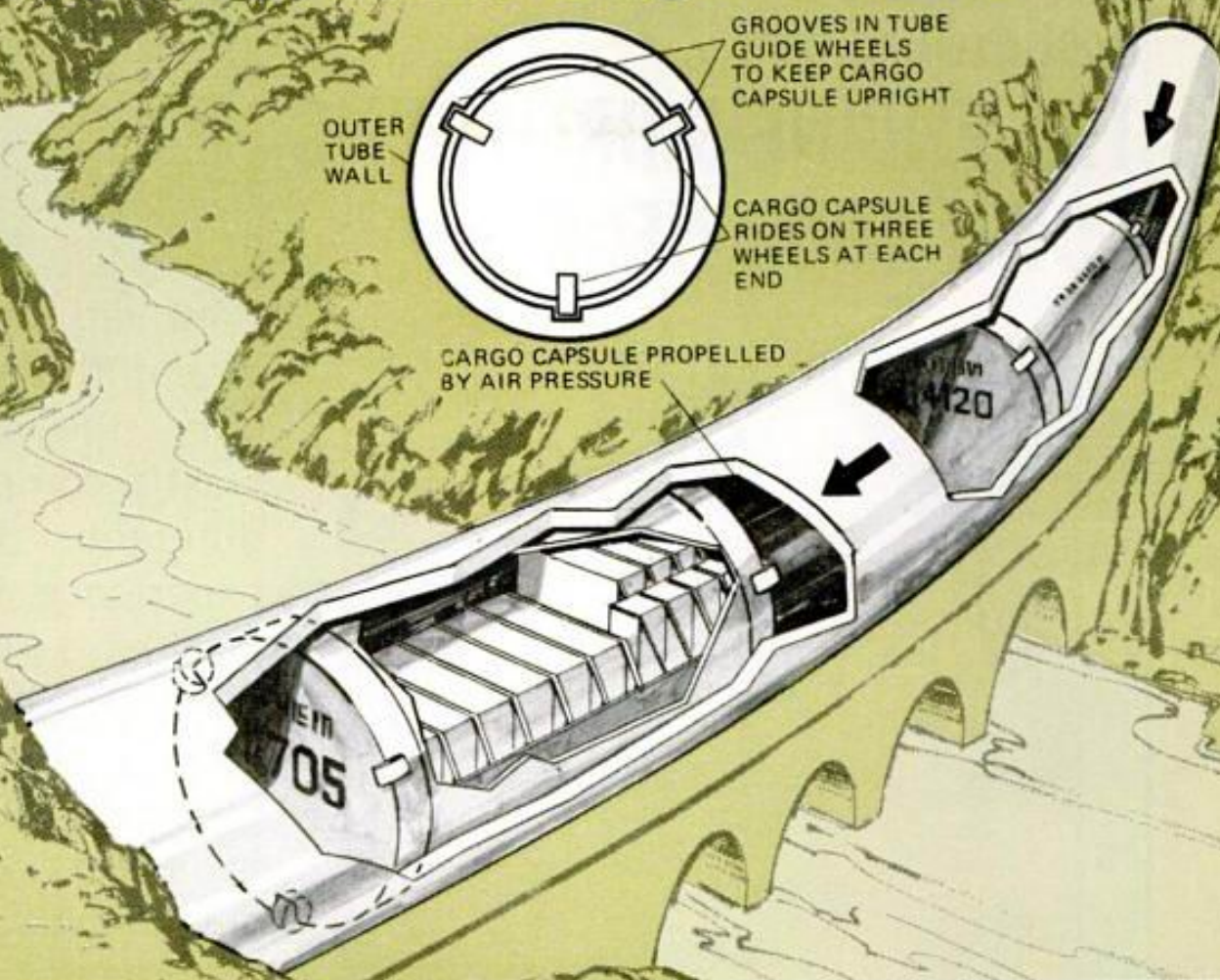
Fast freight:

Remember the pneumatic money-changing tubes they used to have in department stores back in the old days? If you're under 40, you probably don't, but the system was intriguing. The sales clerk would put your money in a small round cylinder, slip the cylinder into a tube and, with a whoosh of air, off it would go flying through a pipeline to the cashier's office, often several floors away. Moments later, back would come your change in the same tube. Now the British Hydromechanics Research Assn. at Cranfield, England, is proposing such a system for transporting freight quickly and cheaply through long underground tubes. The freight would be carried in cylindrical capsules propelled by air pressure, requiring no power or crew. Meanwhile, back in the United States, a Rand Corp. physicist is working on a similar system for passenger travel. In his version, people-carrying pods would be magnetically propelled through vacuum-sealed, frictionless tunnels at incredible speeds up to 10,000 mph, making it possible to cross the country from coast to coast in half an hour!

Coming: Padded landings for parachutists

Parachuting airmen and paratroopers often hit the ground hard enough to cause severe leg and ankle injuries. With this inflatable landing pad, a cushion of air softens the impact and helps to prevent such injuries. The pad is worn collapsed on one foot, something like an overshoe. During the descent, a valve in the toe is pressed with the other foot. This releases a small built-in compressed-air cylinder, inflating the pad in a few seconds. The chutist then places both feet on the cushion just before striking the ground to absorb the shock. The clever device was invented by Henry Doherty, 19B Byrne Court, Wayne, N. J.

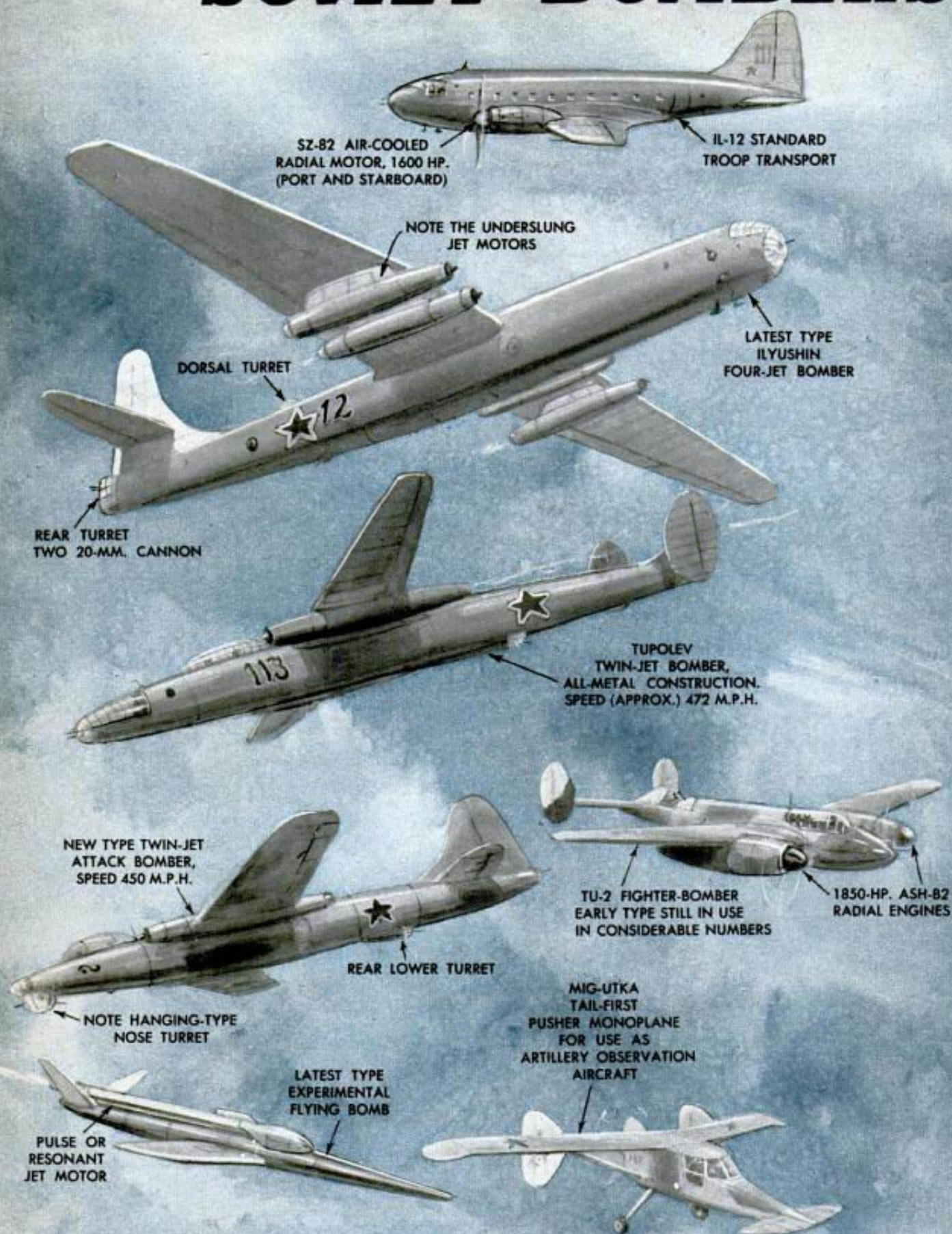
Just blow it through a tube



Lazy Susan airplane hangar

Jockeying small planes in and out of a crowded hangar can be a nuisance, often requiring several ships to be moved to reach another. This rotating hangar is designed to end the fuss. Just push a button and the revolving floor swings around until the desired plane is right at the door. Made by Aerodome Industries of Wichita, Kans., the device is said to house twice as many planes as a conventional hangar of equivalent area. ★★★

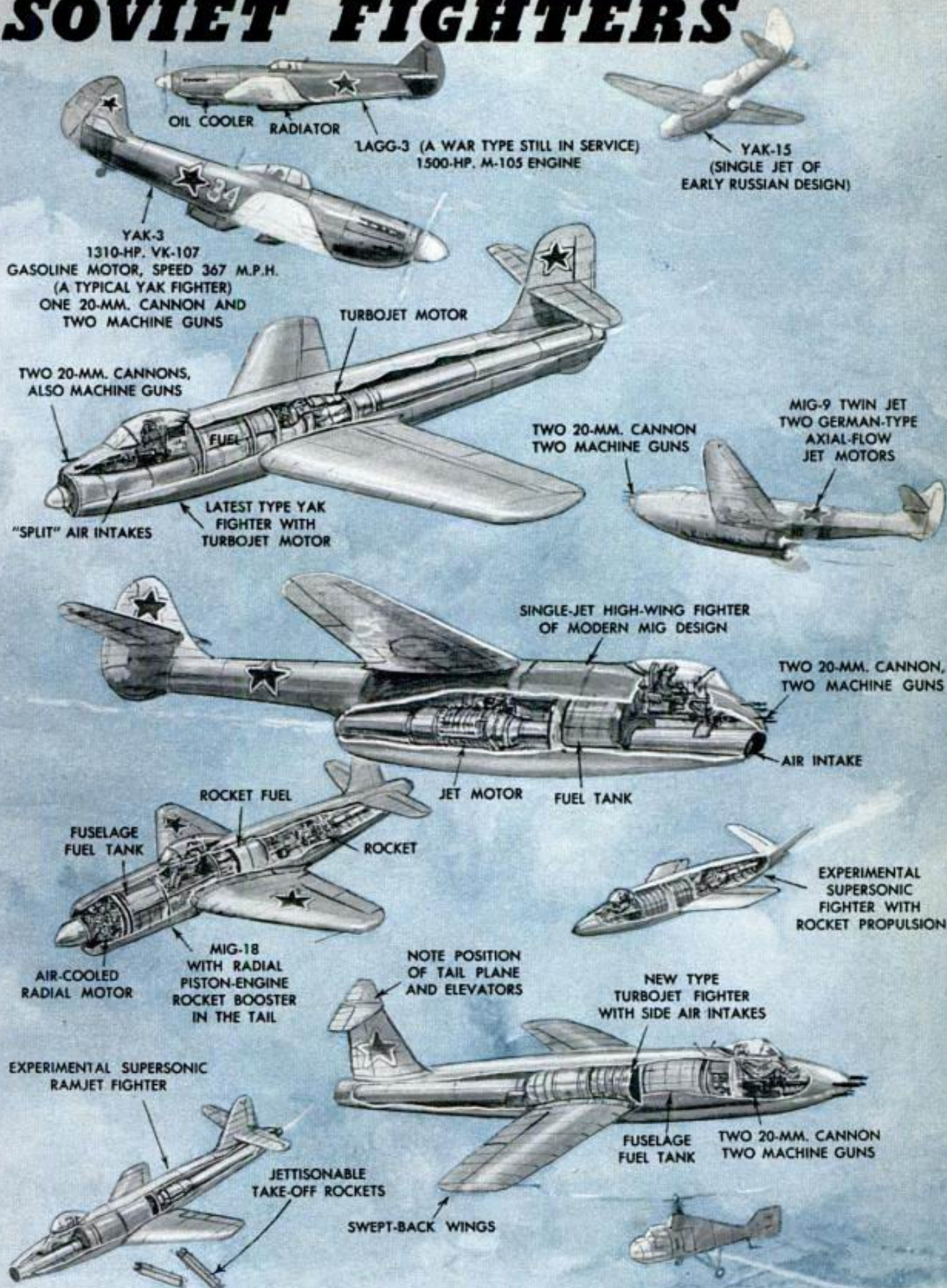
SOVIET BOMBERS



PIECING together scraps of information from many sources, the famed British illustrator, G. H. Davis, presents for *Popular Mechanics* readers his impressions of Russia's front-line fighters and bombers. Most of the details were culled from photos and data in Swedish, Polish, French and British

technical papers and from direct observation at air displays over Moscow. Virtually no information has been released by Russia on new war equipment. Foremost among Soviet designers are Yakolev, Ilyushin, Migoyan, Gurevich, Lavochkin, Tupolev and Sukhoi, aided by German research

SOVIET FIGHTERS



centers and technicians now under Russian control. Other than British Rolls-Royce turbojet engines, most of the power plants have a distinct German touch and Nazi-type rocket motors are used in their latest experimental supersonic craft. Some fuselages strongly resemble American planes,

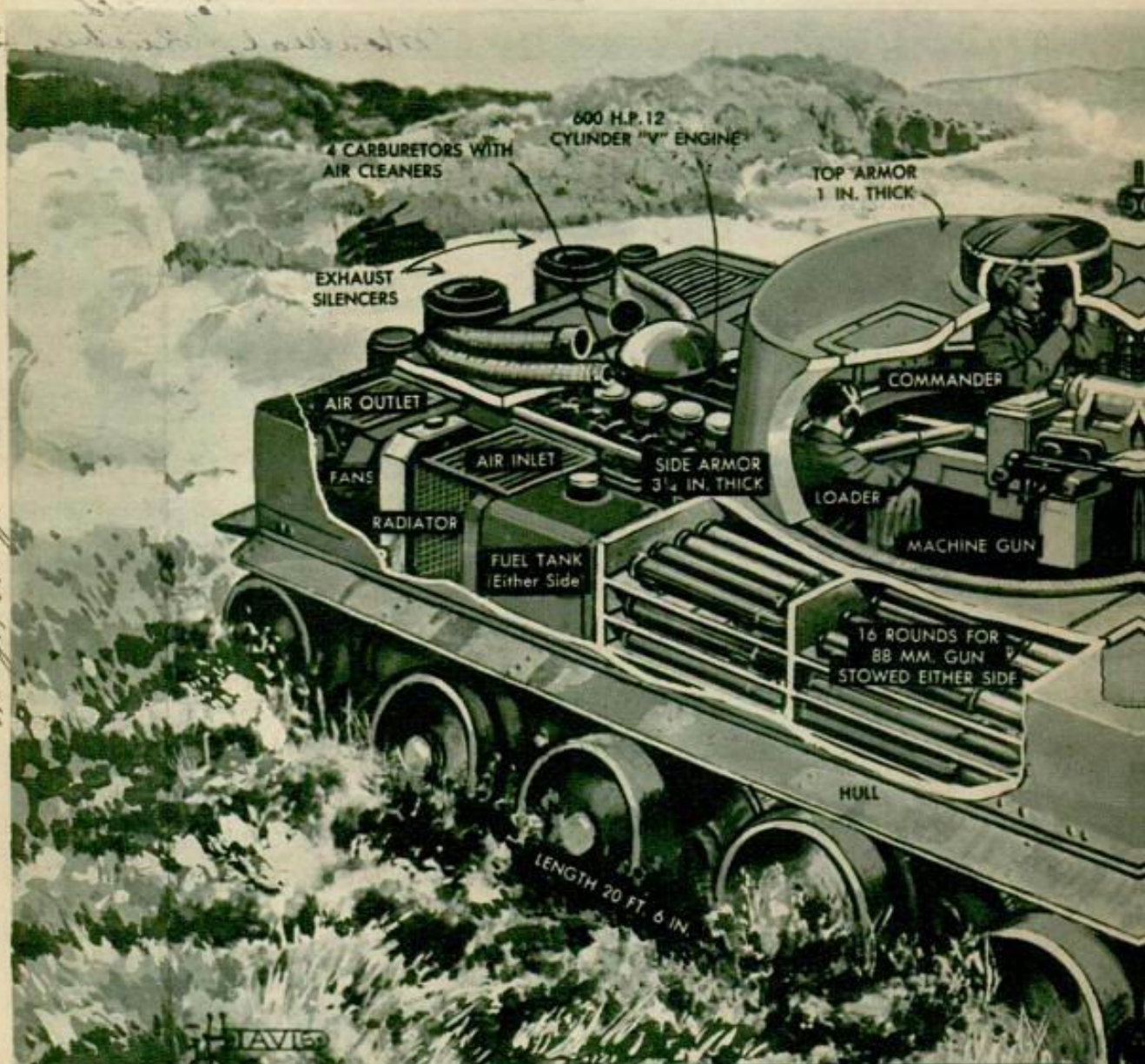
like the new Yak fighter and Republic's F-84 and, earlier, the TU-70 and the Boeing B-29. The Yak's top speed is believed to be near 650 miles an hour. The main armament of Russian aircraft is apparently centered in the 20-mm. Sk-Yak cannon and the 12.7-mm. Beresin machine gun.

Monster Tank Can Cross a River 15 Feet Deep

Allied guns in Africa and on the Russian front shattered the myth of invincibility of the German Mark VI "Tiger" tank long before the secrets of this 56-ton monster were revealed. The main armament of this cumbersome "fortress on tracks" is an 88-mm. gun which fires shells three feet long. The gun has a special mounting and is fitted with a special muzzle brake to reduce recoil. Rate of fire is slow due to the difficulties in handling the big shells which are

stored in horizontal bins. Additional fire-power is afforded by two 7.92-mm. machine guns. A watertight compartment for the engine at the rear, rubber seals fitted to all the main openings, and air intakes that have telescopic extensions enable the tank to cross rivers 15 feet deep. The "Tiger" is operated by a five-man crew, has a top speed of 17 miles per hour, and a cruising radius of about 75 miles. Lack of maneuverability makes the tank an easy target.

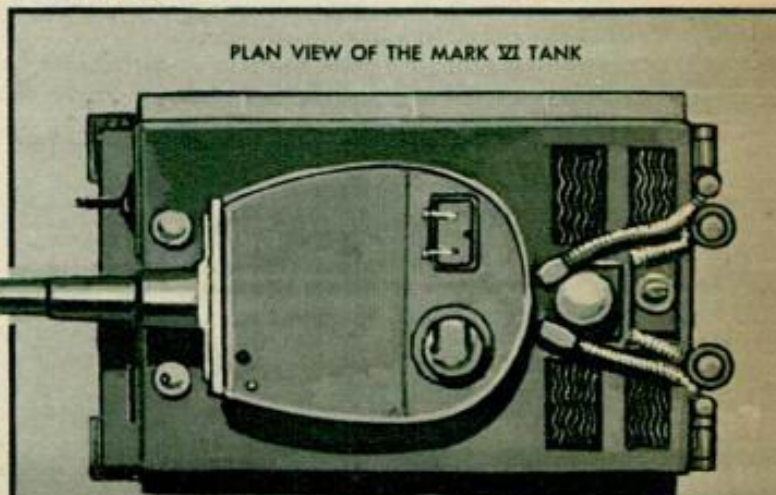
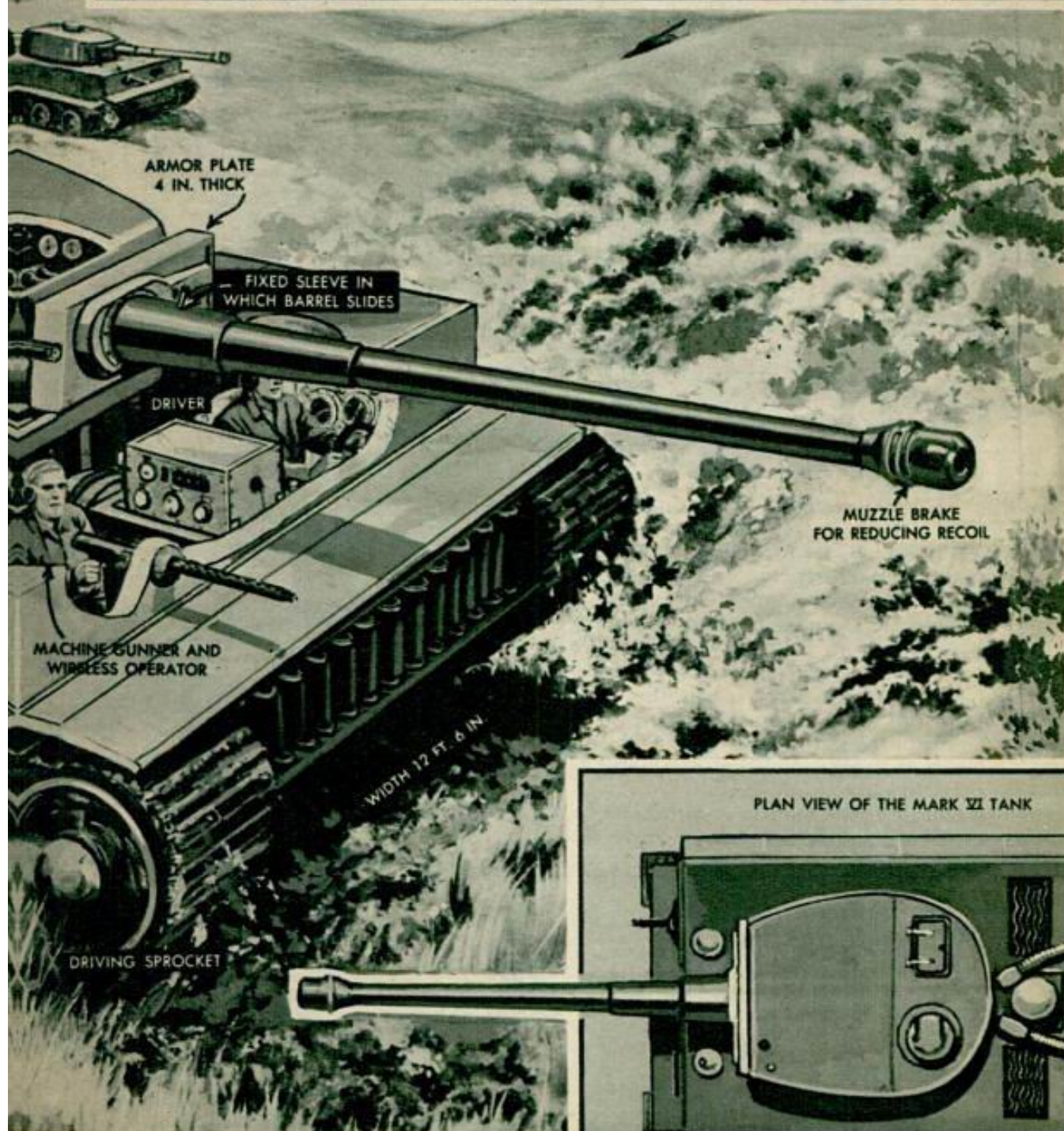
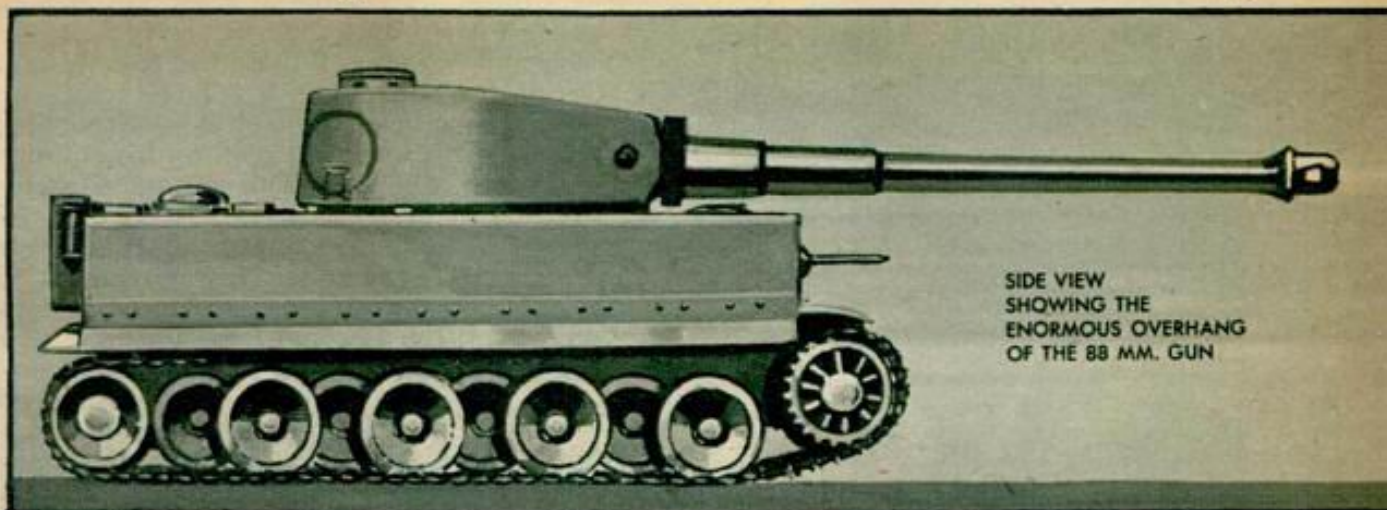
International News Photo.
 235 C. 45th St.
 N. Y., N. Y.



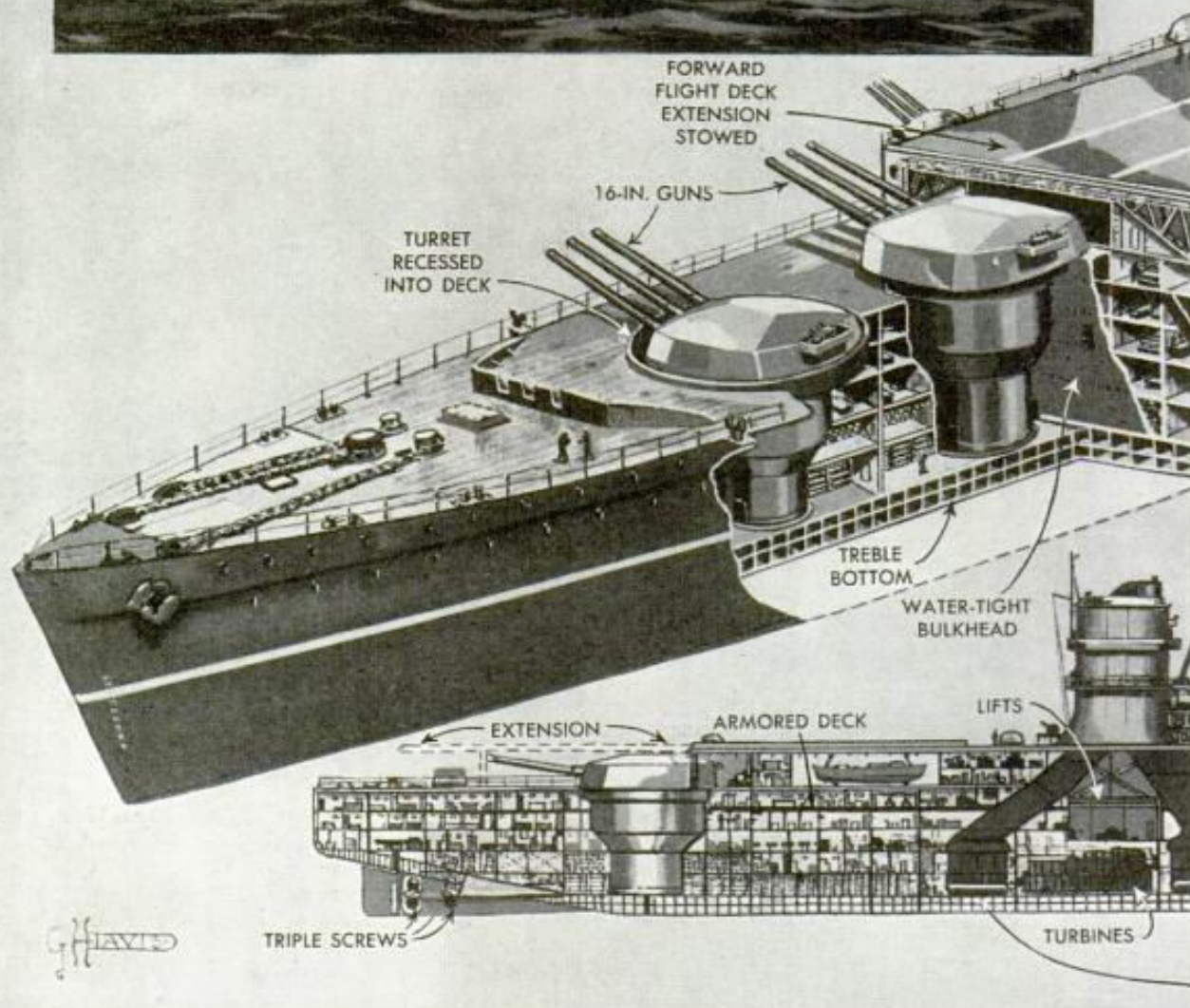
THE GERMAN "TIGER" TANK IS CAPABLE OF BEING MADE WATERTIGHT AND CROSSING RIVERS, ON THE RIVER BED, TO A DEPTH UP TO 15 FEET



German "Tiger" Fires Shell Three Feet Long



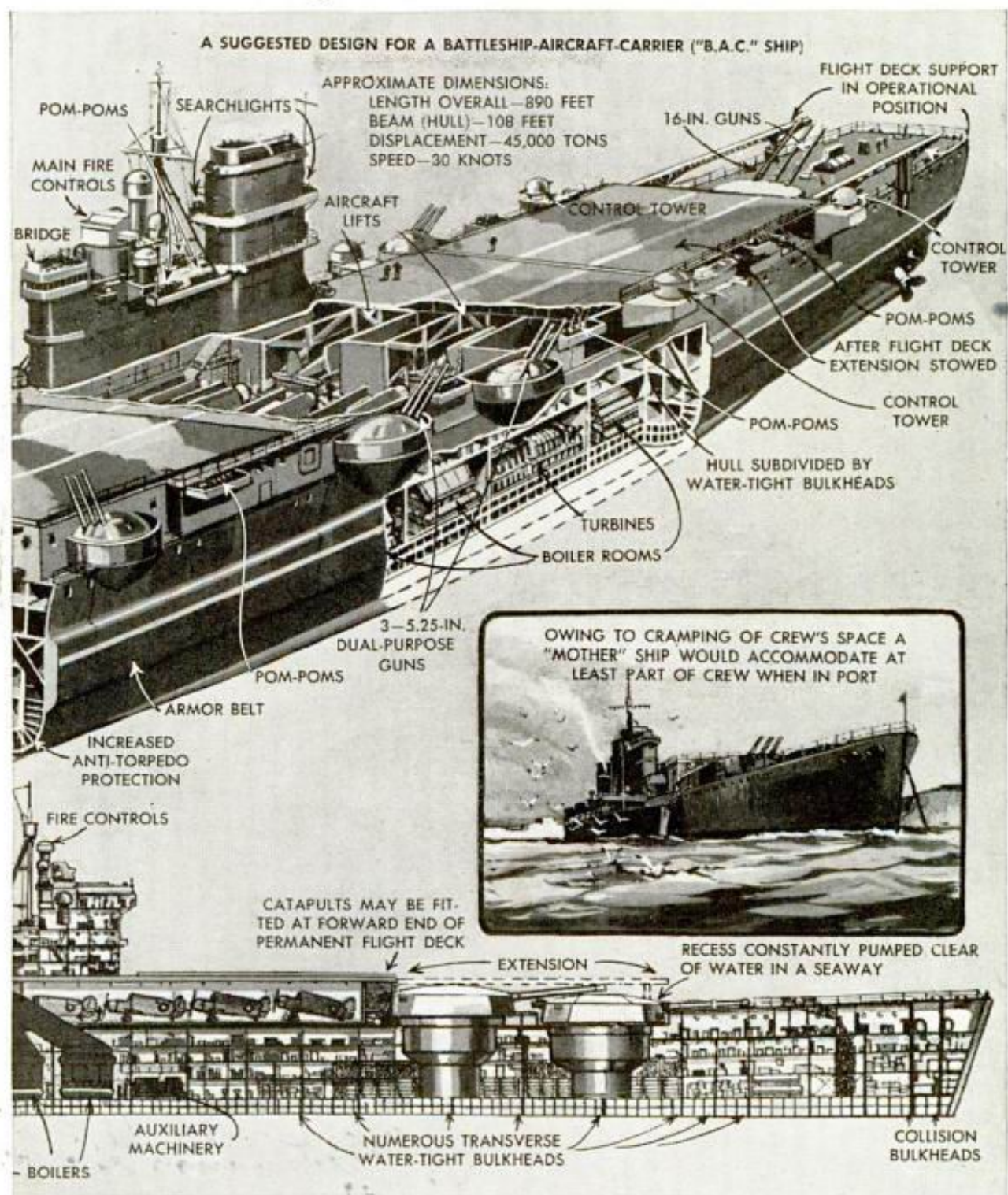
London Electra type Agency
134 Fleet St London, England
Battleship-Carrier Could Guard Itself in Action
m 9/16



Vulnerability of the aircraft carrier in its present form, coupled with the helplessness of the most powerful battleship without guardian airplanes, have inspired a proposal in England for a combination battleship-carrier armed with turrets of 16-inch guns which could be recessed into the deck to accommodate an extensible flight deck. It would be a tremendous vessel of probably 45,000 tons, incorporating the full armament of the dreadnaught, both

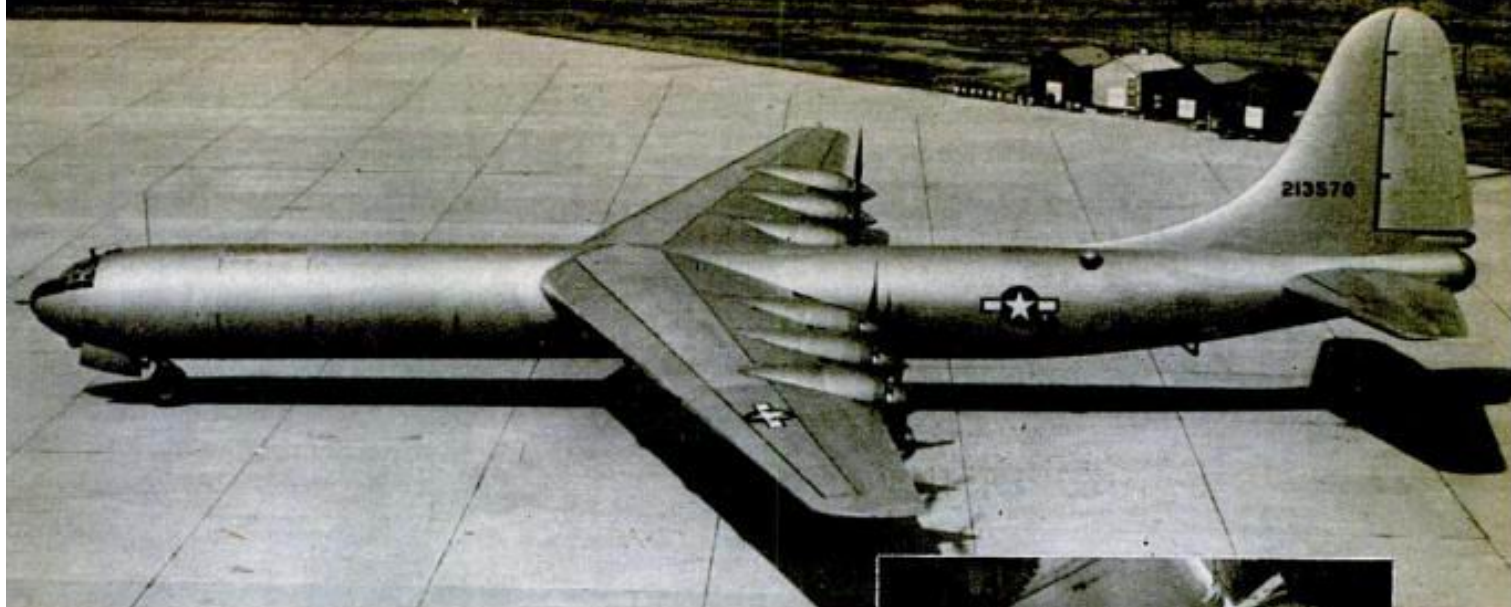
primary and secondary, and would be heavily armored against attack from above or below, with a treble bottom, antitorpedo belts and liberally protected throughout by numerous watertight bulkheads. A ship with these combined functions would necessarily be huge, requiring the immense storage capacity for shells and powder magazines to supply the big guns and anti-aircraft batteries on a long cruise plus the tremendous space needed for hangars, air-

Extensible Flight Deck Covers 16-Inch Turrets



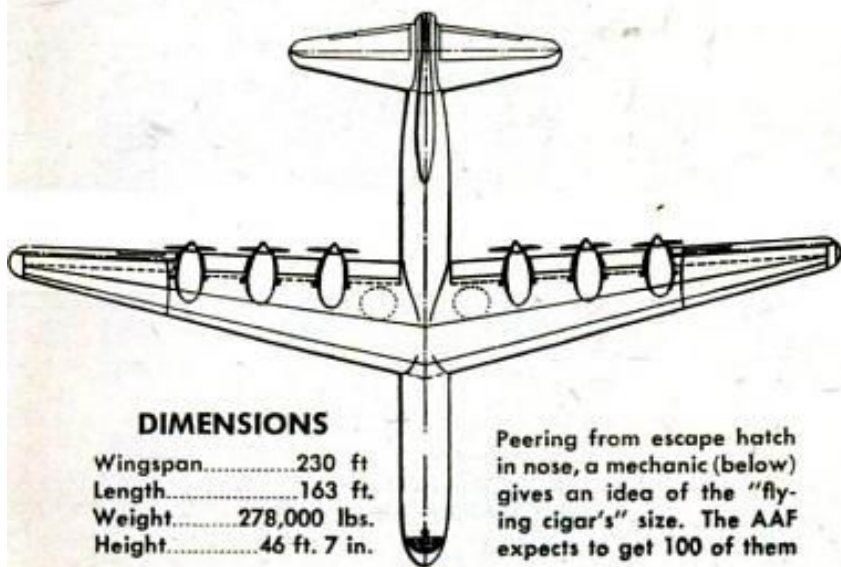
craft repair shops and gasoline storage tanks belowdecks. The compromise would inevitably cramp the quarters of the crew. The battleship-carrier's brood would likely comprise about 15 fighter planes plus two or three torpedo-reconnaissance craft. The central portion of the upper deck would be a permanent flight deck, perhaps with catapults at the forward end. From this permanent deck the extensible sections would extend fore and aft, rolling on

steel bridgework supports which pivot against the end of the permanent deck when not in operation. A heavily armored deck at the level of the hangar floor would protect the vital parts of the vessel from aerial bombs. Two elevators from hangar to flight deck would shuttle the aircraft quickly. The single funnel and the "island" structure for the bridge and main fire controls would be placed at one side as they are on present aircraft carriers.



ARMY'S B-36 BOMBER

So big you have to ride a "railroad" from tail to cockpit, describing the B-36 requires generous use of superlatives. The fuselage of the world's largest bomber has cubic space equal to 10 large-size living rooms. It has lifted 139 tons. Crewmen stretch out on a four-wheel scooter and use an overhead trolley to pull themselves through the 85-foot tunnel



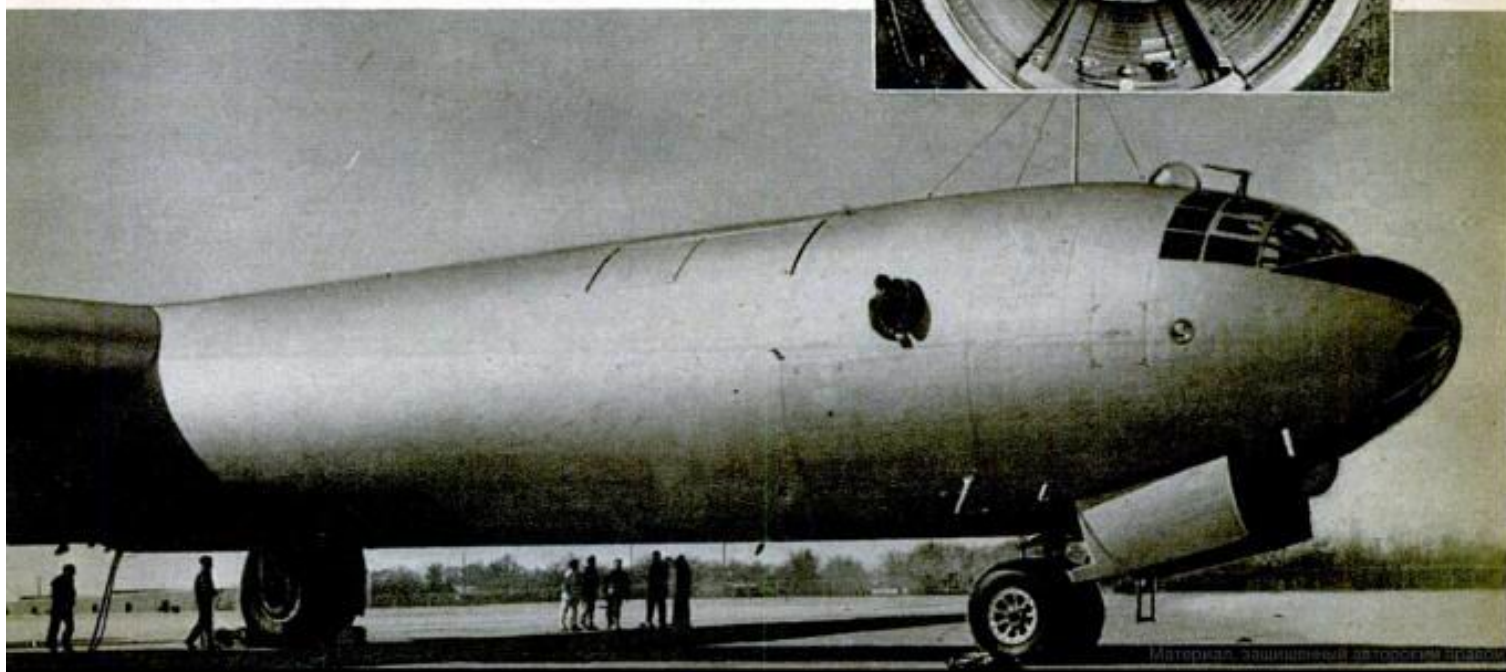
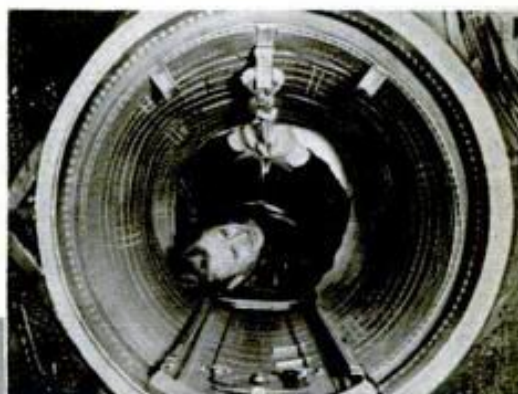
DIMENSIONS

Wingspan.....230 ft
Length.....163 ft.
Weight.....278,000 lbs.
Height.....46 ft. 7 in.

Peering from escape hatch in nose, a mechanic (below) gives an idea of the "flying cigar's" size. The AAF expects to get 100 of them



Inner tubes alone for these nine-foot-tall tires weigh 200 pounds. Below, tunnel scooter



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WRITTEN SO YOU CAN UNDERSTAND IT

Vol. 78

DECEMBER, 1942

No. 6

The AGE of AIR



By Colonel Edward S. Evans

President of Evans Products Company

WHO could have envisioned in 1928, when a dozen young men were making the first glider experiments at the University of Michigan, that the crude ship then used was the forerunner of what would ultimately be one of the world's great means of transportation?

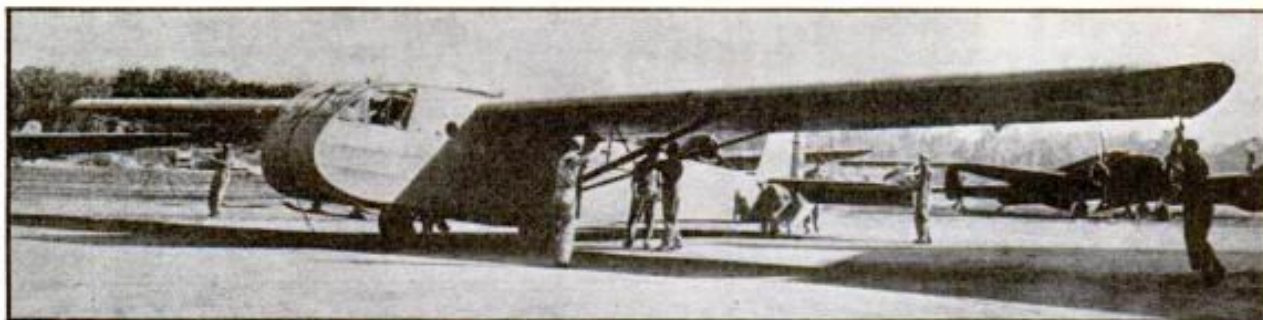
These members of the first glider club

Three huge cargo gliders taking off from an air depot of the future are in the air before the giant tow plane. At upper right, stowing freight in a glider

DECEMBER, 1942

1

*Wilma Lee, Public Relations,
Evans Prods. Co., Tullerton at Greenfield,
Detroit, Mich.*

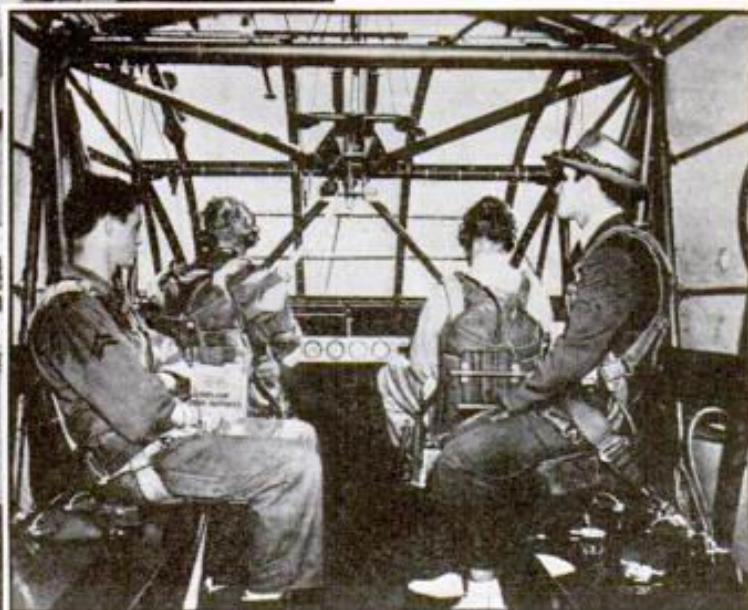
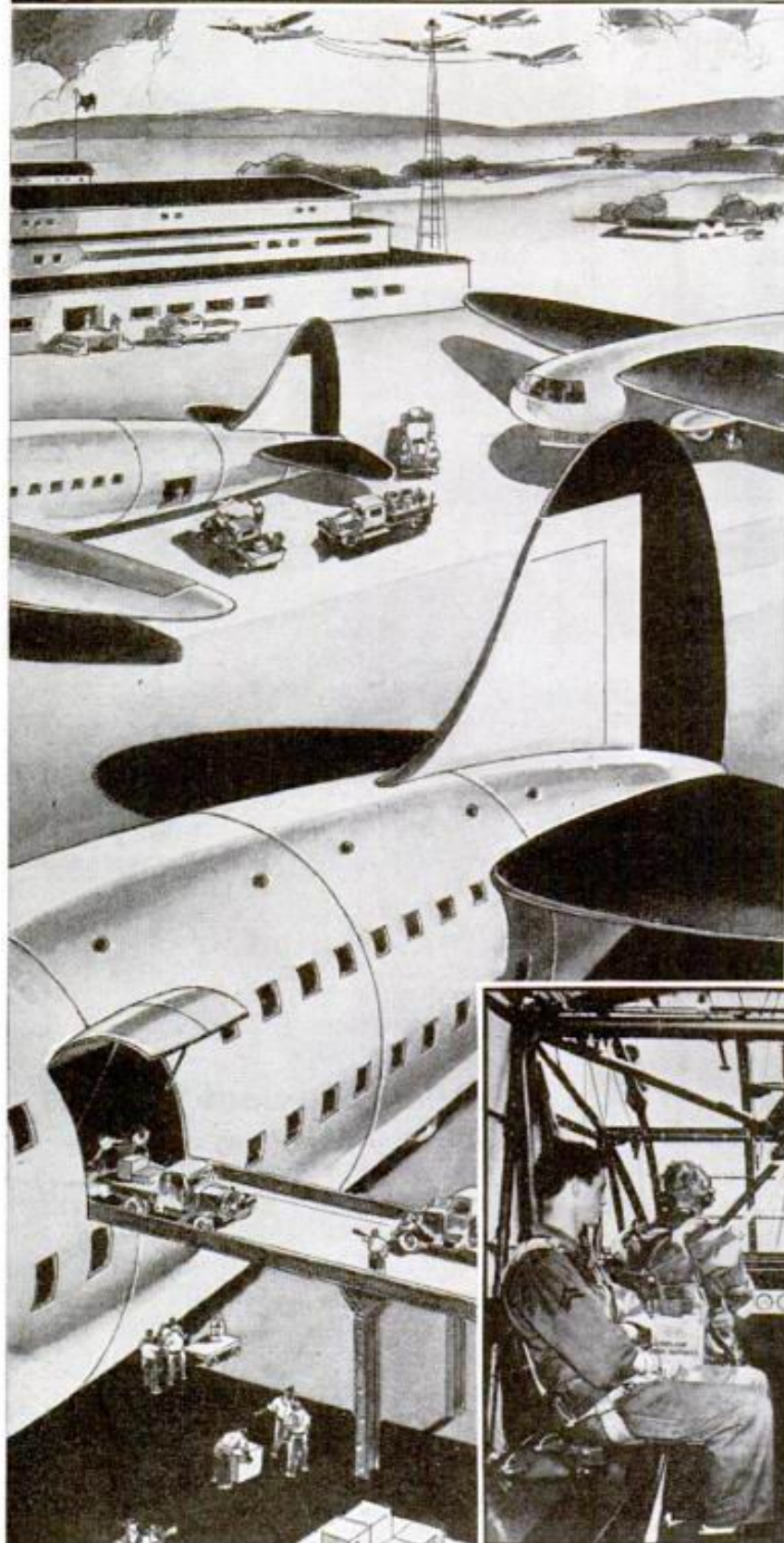


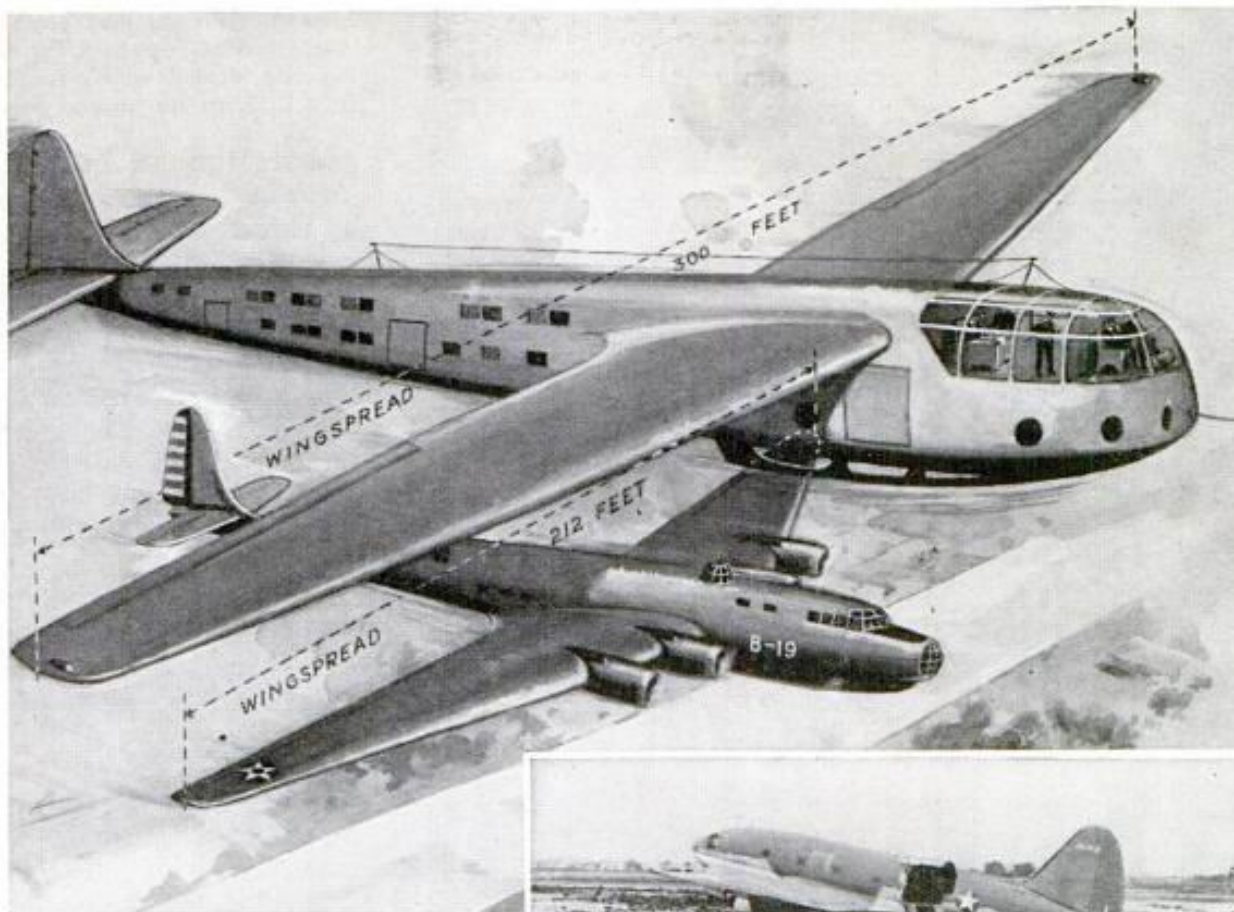
15-seat gliders of U. S. Airborne Command are only a beginning

of America, which was formed under my sponsorship, learned the delight of being pulled into the air with a rubber cord and gliding gently to the ground several hundred yards away. Some of these same young men today are still flying gliders, beautiful ships known as sailplanes which have established records of distance, altitude and duration that are almost unbelievable.

Looking toward tomorrow, we can see the same principle employed for motorless cargo ships towed by tractor or tug planes, carrying enormous loads of freight or deliver-

All perishable and first class cargo eventually will be shipped economically by air, says Colonel Evans. Left, air freight terminal; below, cockpit of army glider





The author foresees a motorless freight and passenger ship with a 300-foot wing spread—nearly 100 feet wider than that of the B-19, drawn to same scale, above



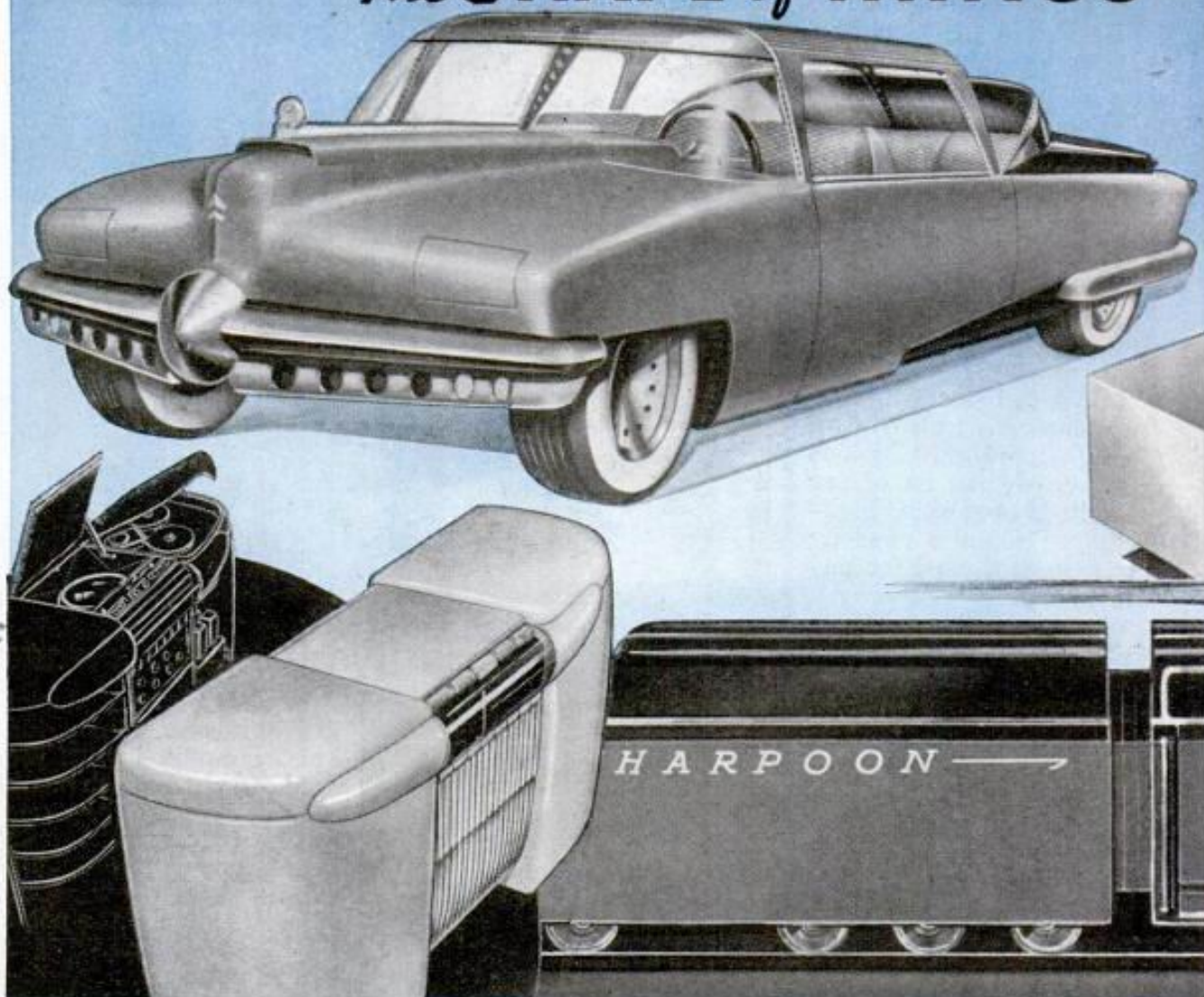
Transport planes of the Airborne Command (above and at left) are vast enough to carry army jeeps and large number of men

vibration, no noise, with a wing span and a speed which will assure smooth riding. One employing such facilities can rest comfortably at night and arrive at his destination as rested as if he had slumbered in his own bed.

ing human cargo in the most quiet and delightful way ever known to man; ships that will carry twenty tons or more freight or up to 100 passengers, with no engine

Freight thus transported could be delivered in quantity at 200 miles per hour and at a cost well within the range of economical shipping; in other words, somewhere

The SHAPE of THINGS



At top is one of Raymond Loewy's conceptions of the automobile of the future. Below, at left, radio-television set designed in plastics cabinet by Sundberg and Ferar, including a magnetic-wire phonograph

*580 7-5th Ave.
N. Y., 19, N. Y.*

By Roderick M. Grant

*Stephenson Bldg.
Detroit, Mich.*

LIFE will never be the same again. The techniques and materials conceived under the impulse of war must inevitably bring vast changes in our ways of living, greater comforts and greater efficiency.

Home has never been an efficient thing. You pour more than half your fuel up the chimney and through the walls and windows. You furnish the house with lush carpets and overstuffed furniture that erupt clouds of dust at every movement. Paint and wallpaper perennially wither and fade. Summer dampness mildews, winter heat dismembers furniture. You tramp numberless miles from refrigerator to stove to dining table and back again.

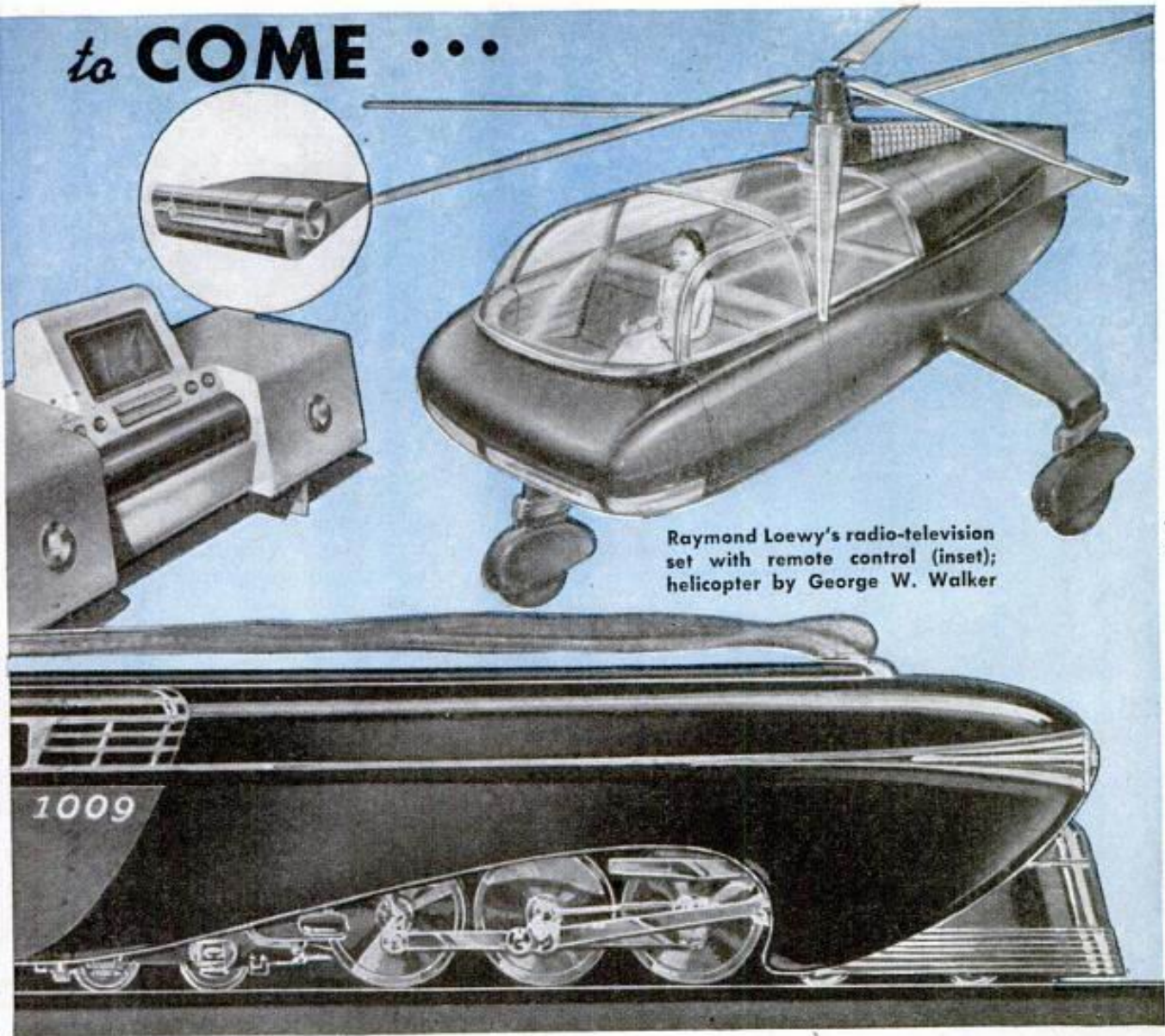
Your automobile was an enormity of chrome to be traded in at the first hint of a rust spot. It was heavy, it drank gasoline like a lord, it had blind spots, but it was

pretty and fast. You traveled in railroad cars probably twice as heavy as they need be, behind locomotives that delivered the goods effectively despite a technically inefficient power plant.

This is not to say that your p.f.c. will come home to a pink plastic house with dustfree air conditioning and a rear-engine-car traveling 50 miles on a gallon of 150-octane gas. But this is a promise that evolution of better living will begin when the war ends, for it has begun already on the drawing boards of American designers who are shaping the future for our builders and manufacturers.

When designers' dreams come down to earth, of course, economic considerations will dictate their form. Practicality ruled, for example, in the designing of a functional utility unit for the home, conceived by

to COME ...



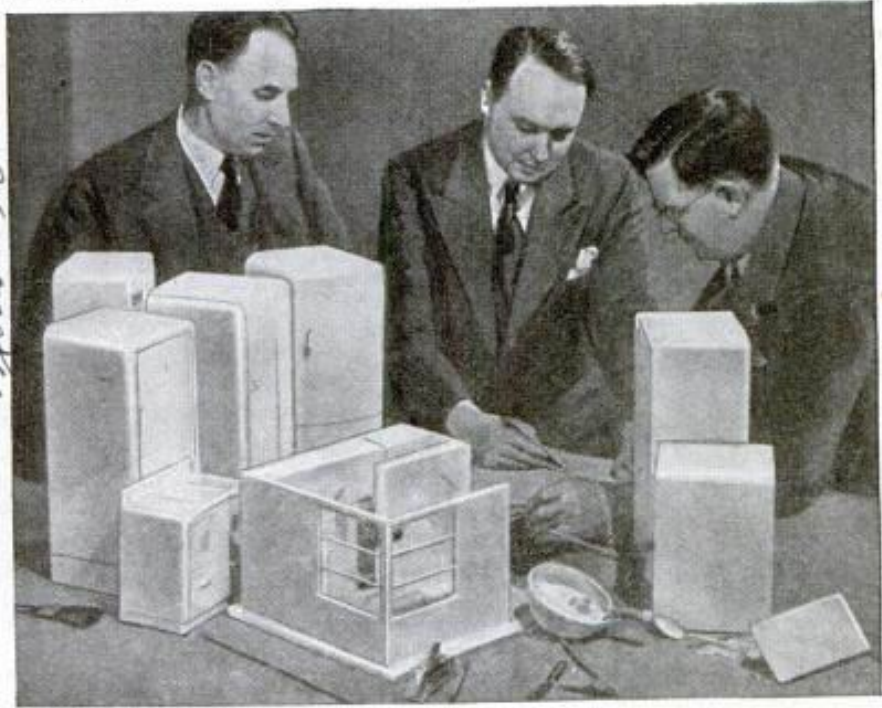
Raymond Loewy's radio-television set with remote control (inset); helicopter by George W. Walker

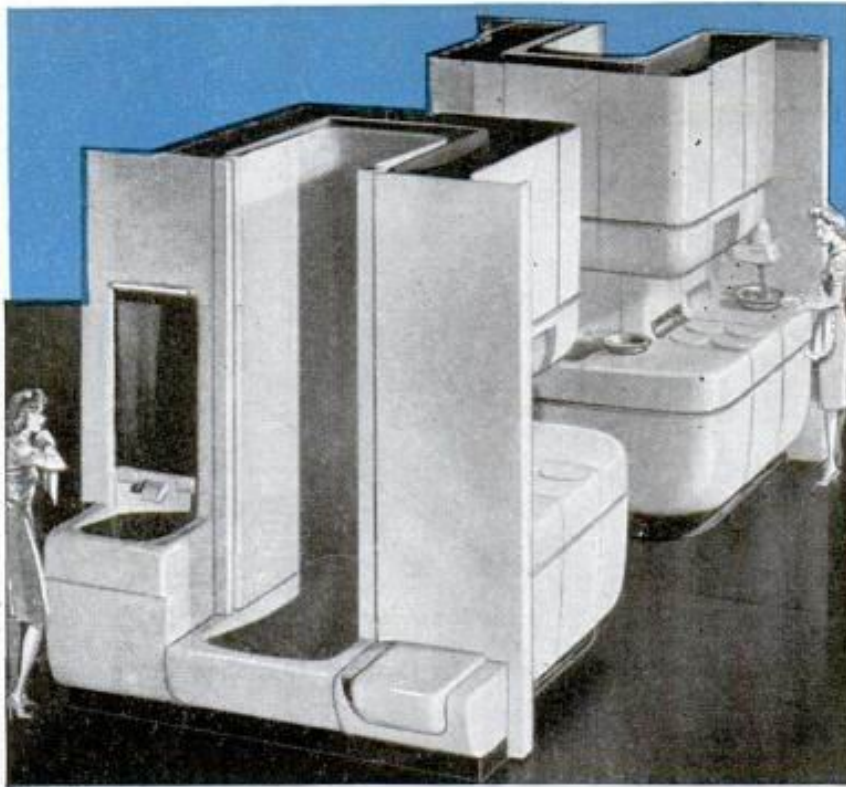
340 N. Milwaukee St.
Milwaukee 2, Wis.

Sundberg-Ferar of Detroit for the Virginia Lincoln Corporation. In this unit, the newly-developed low pressure molding technique of forming large pieces of resin-impregnated fibrous materials is used to form bathroom and kitchen fixtures integral with standardized interchangeable wall sections. All plumbing, wiring and electrical ducts are built in, and quickly connected by flexible connections to gas, electric, sewage and plumbing outlets built into the foundation.

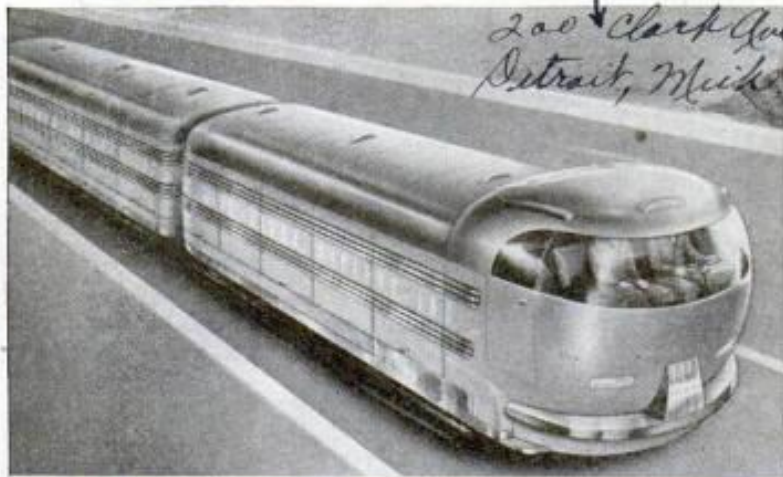
The kitchen has a built-in refrigerator with drawers instead of doors; a flick of the fin-

Notice "harpoon" shape of steam locomotive designed by Brooks Stevens. Below, engineers of Serval, Inc., study models of household equipment





Tub and shower of bathroom (Sundberg & Ferar) fit into "U" of kitchen unit. Below, highway "livestock train" sketched for Timken-Detroit Axle Co.



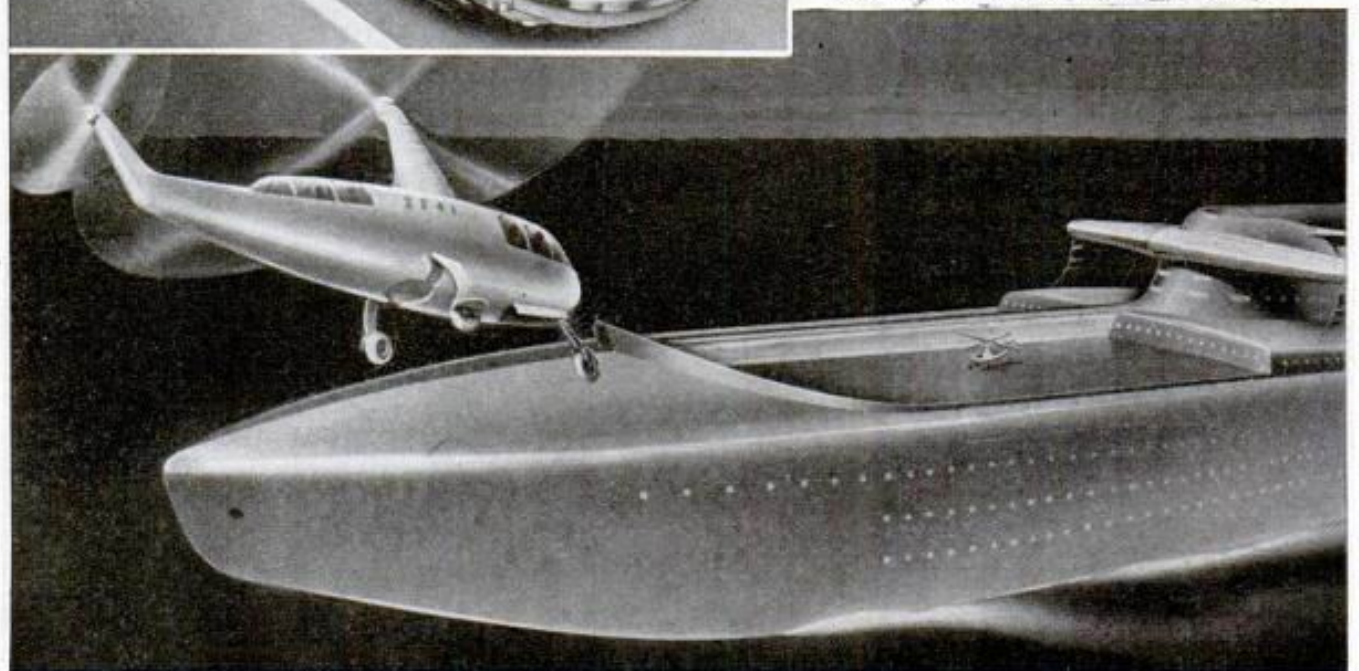
ger releases the catch and the transparent-front drawer rolls forward on a slightly inclined track. The sink, recessed into the wall, includes a plastic shower head for rinsing dishes, its hose automatically drawn up on a hidden reel when released. A compartment at the left of the sink contains air-conditioning and heating units and the hot water supply.

On the other side of the unit is the bathroom, with built-in fixtures conveniently arranged, and fluorescent lighting.

Many a home owner will go shopping for new heating plants after the war, and there will be new heating "packages" of diminutive size and high efficiency. Already there is promised a heat-control system, built by

Minneapolis-Honeywell Regulator Co., which will permit sectional regulation so that the living room can be maintained at 72 degrees, the bedroom at 65, the garage and attic at 50 or any desired level. This heat regulator, already used in large public buildings, can be installed in many existing home heating systems after

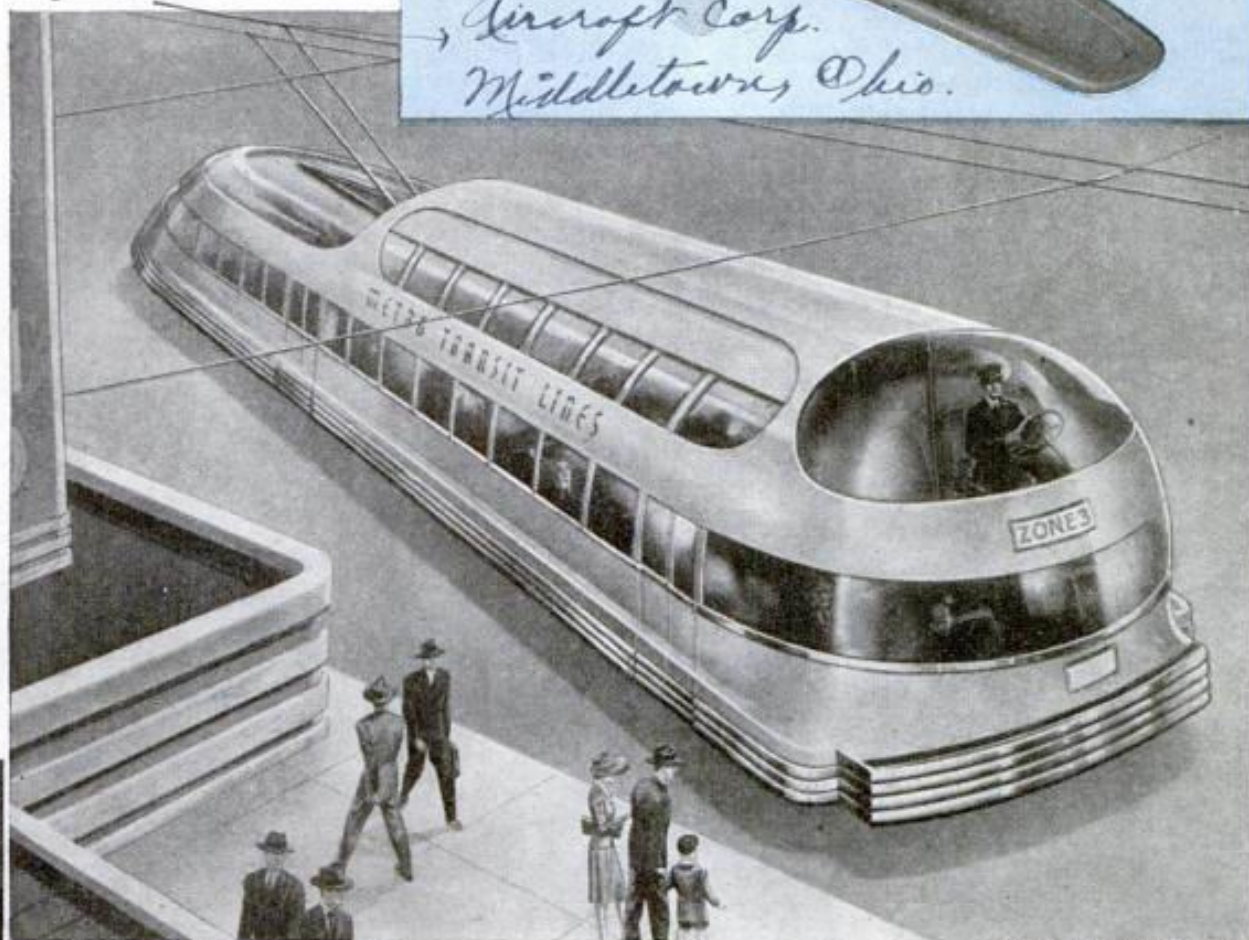
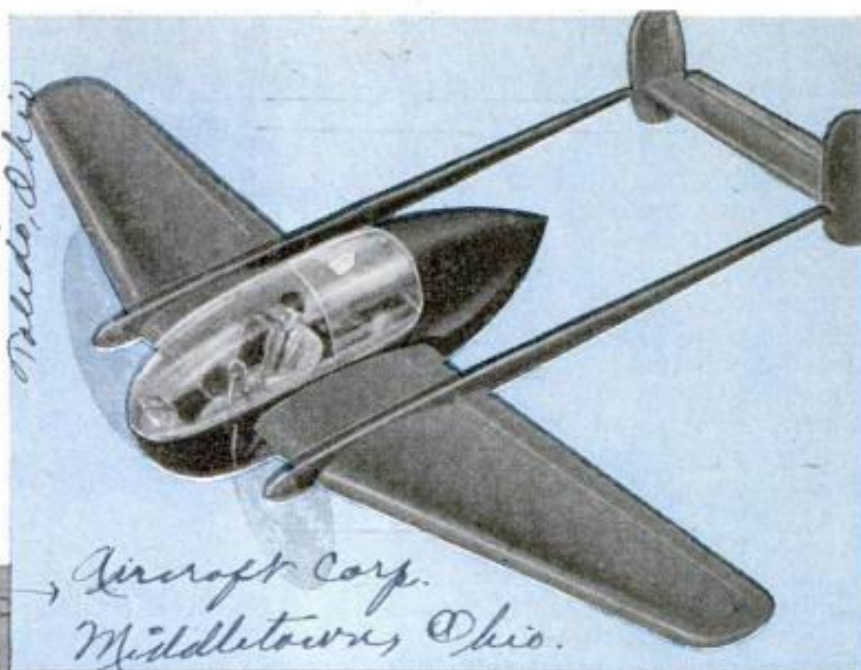
Turbo-electric liner with helicopter on deck, conceived by Raymond Loewy



the war to modulate the flow of heat to each room or section as required, wasting not a degree where it is not needed.

The home planners of the Owens-Illinois Glass company include in their preview a plastic refrigerator with an icewater tap, ice cube ejector, deep freeze unit, ultraviolet lamp to sterilize food, and a circular central section

The four-place family plane at right is an artist's suggestion of an Aeronca plane of the future



This twin-deck trackless trolley with the driver upstairs, and with a sky-view "roll-back" roof, is proposed by one industrial engineer

with revolving shelves. They also suggest an electric eye that will see you coming and open the swinging door as you carry a tray of dishes from diningroom to kitchen . . . a waste pulverizer that chews up table scraps and old bottles . . . a cordless electric iron . . . windows that open at touch of a pushbutton.

Westinghouse looks forward to completely air-conditioned homes with dust and dirt collected from the air electrostatically by home-size Precipitrons . . . lockers to quick-freeze foods from your post-victory garden . . . automatic washing machines with electric driers and ironers.

It is pretty generally agreed that the next automobiles

built will be modified 1942 models. It is the car after the next that our designers are planning. George W. Walker, Raymond Loewy, Brooks Stevens, Sundberg and Ferar all have their versions of the streamline sedans of the future, some of them rear-engine models, nearly all emphasizing visibility through plastic windows and at least partly transparent roofs, and a minimum of corner-post obstructions. Family-size helicopters are also on the drawing boards, and Raymond Loewy as consultant engineer for the Greyhound Corporation has sketched a huge helicopter-bus which would have terminals on the roof of motor bus stations.

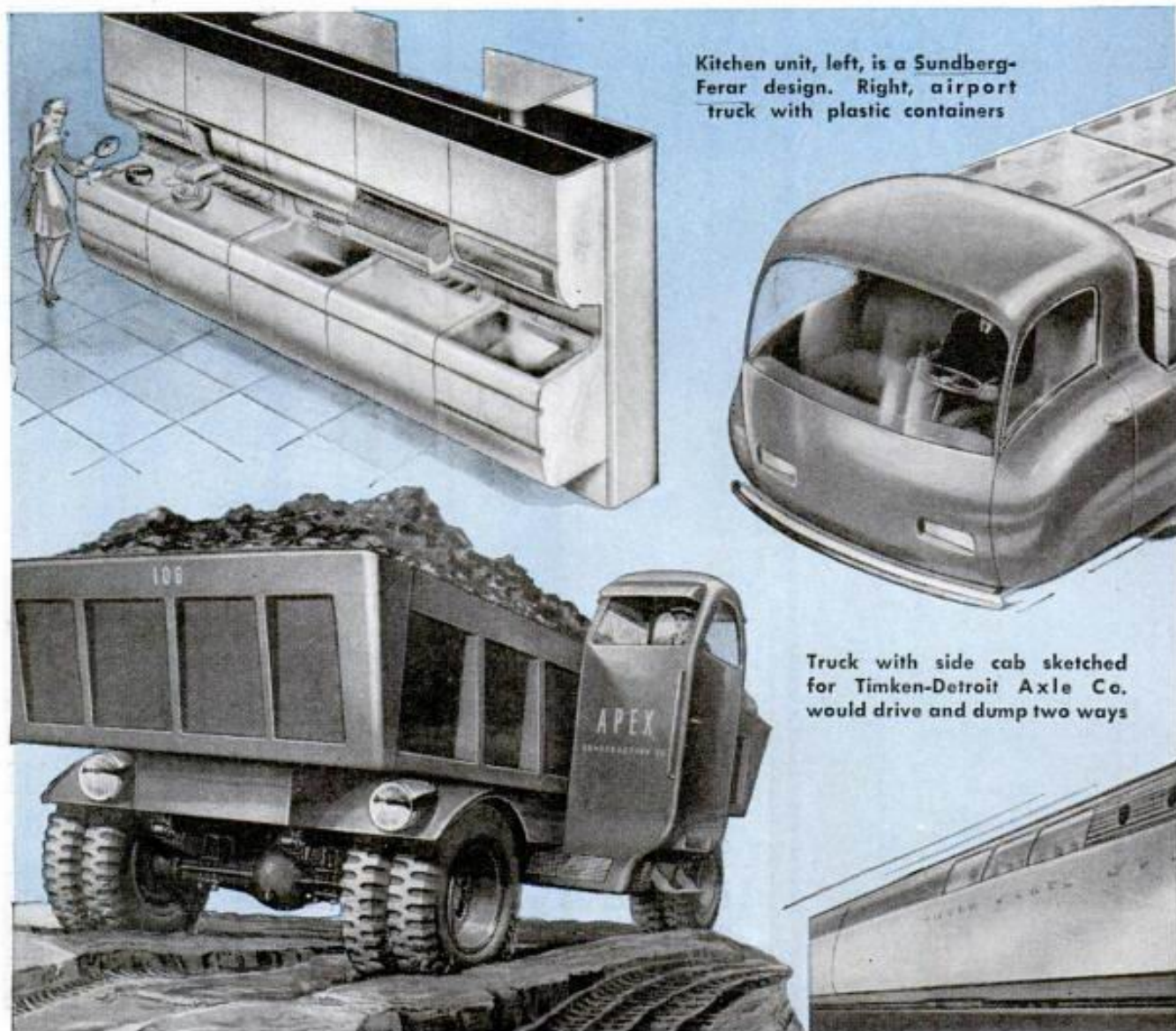
From the Timken-Detroit Axle company comes a whole album suggesting the "shape of things to come" from the truck and bus builders when their energies are no longer absorbed in building tanks and aircraft and military trucks. These "vehicles of tomorrow" sketched for the company by Lurelle Guild range from a twin-deck trackless trolley with a sky-view, roll-back roof to an earth-moving dump truck with an off-

set cab at one side, steering-driving axles at both ends permitting the truck to be driven in either direction without turning around, and dumping its load both fore and aft. Timken-Detroit also visualizes delivery trucks with merchandise display panels in the sides, airport trucks carrying plastic containers loaded with packaged goods for air cargo shipment, and huge tractor-trailer combinations specially designed for hauling livestock, milk, oil, passengers, produce.

"The day of the 'all-purpose' truck is gone," the Timken-Detroit company points out. "Just as livestock differs from household goods, so should the trucks and trailers that carry each be designed for its particular kind of load. . .

"From the crucible of war have come great technical advances. . . Fuels that get more power from new engines. Lighter but stronger metals that reduce over-all weight, yet serve better the purposes of safety.

"All this is on the side of vastly improved performance, longer life, greatly reduced



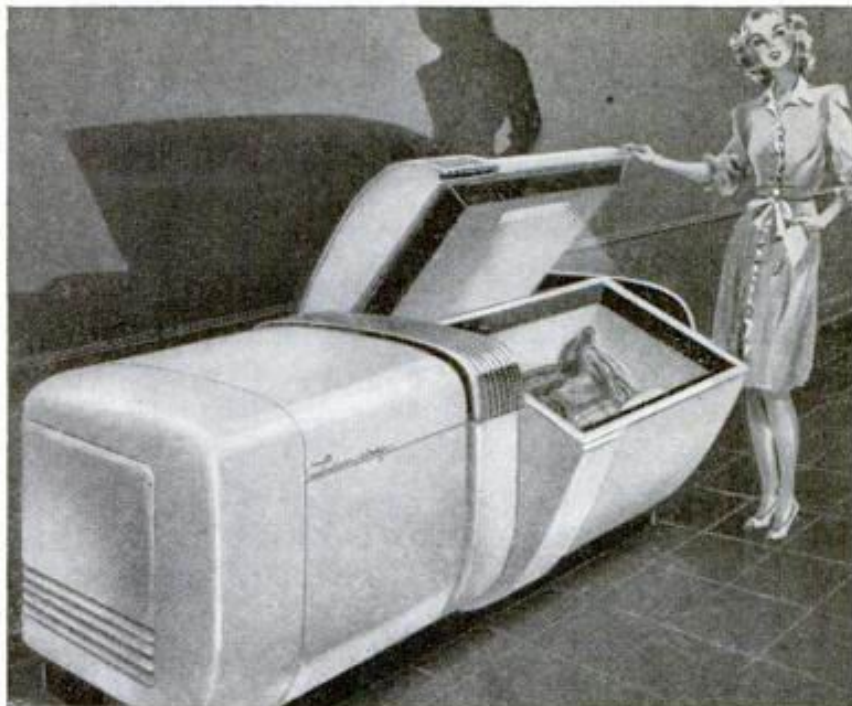
Kitchen unit, left, is a Sundberg-Ferar design. Right, airport truck with plastic containers

Truck with side cab sketched for Timken-Detroit Axle Co. would drive and dump two ways

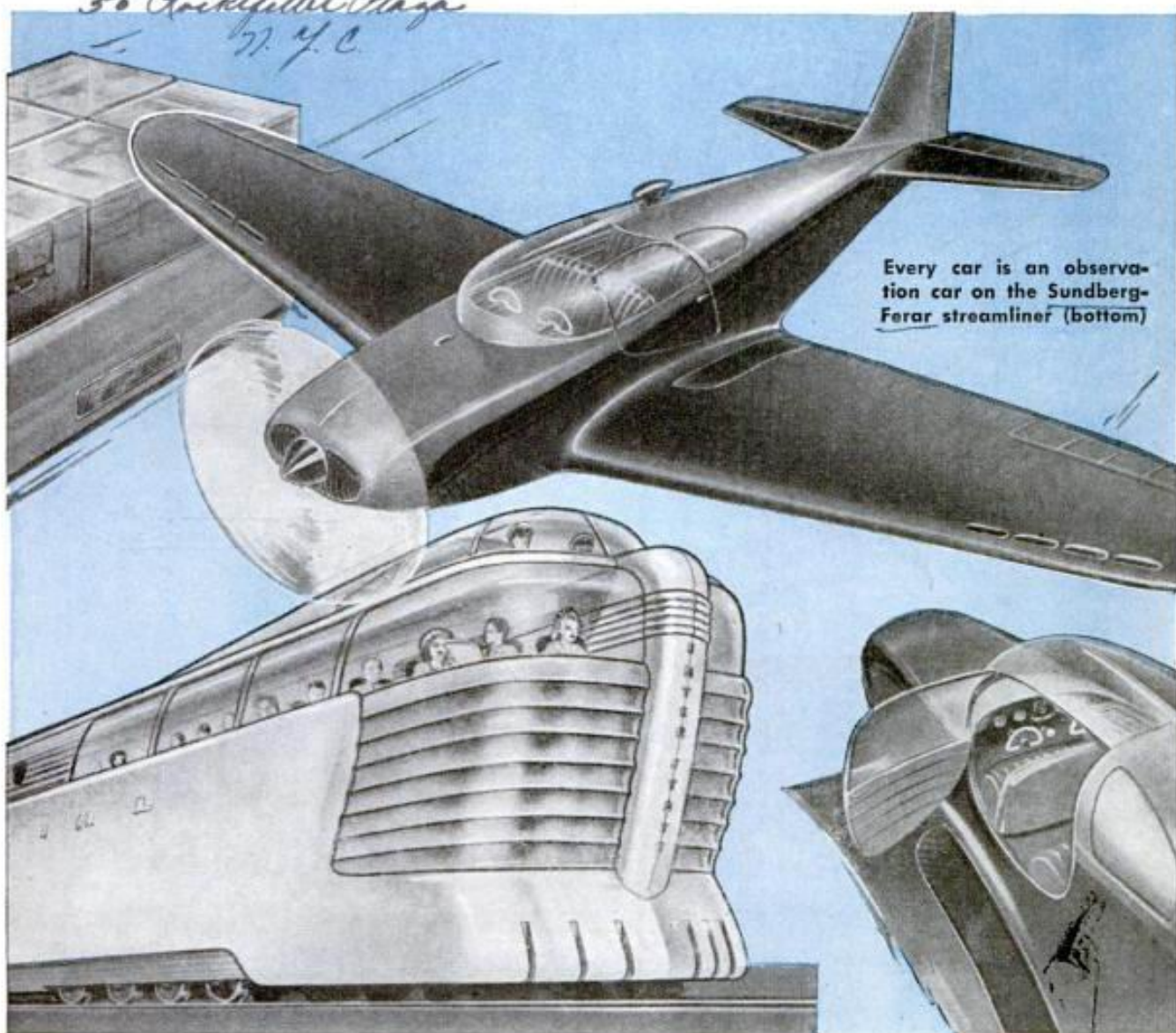
operating and maintenance cost. And already on the drawing boards of designers are the sketches of bodies that will increase carrying capacity, reduce 'drag,' promote safety, facilitate loading and contribute greatly to the comfort of all who drive or ride."

Surveys have indicated that more than 1,000,000 families will undertake home improvements shortly after the war, 1,000,000 new homes per year will be built, and there is a vast market accumulating for new automobiles, radios, television and FM, refrigerators, washing machines and so on and on.

As Norman Bel Geddes and company, industrial



The home freezer unit is a Brooks Stevens design. The same artist borrowed from automotive styling in prophetic sketches of lightplane, below



Every car is an observation car on the Sundberg-Ferar streamliner (bottom)



Timken-Detroit Axle Co.

Tomorrow's light delivery truck may have changeable merchandise showcase

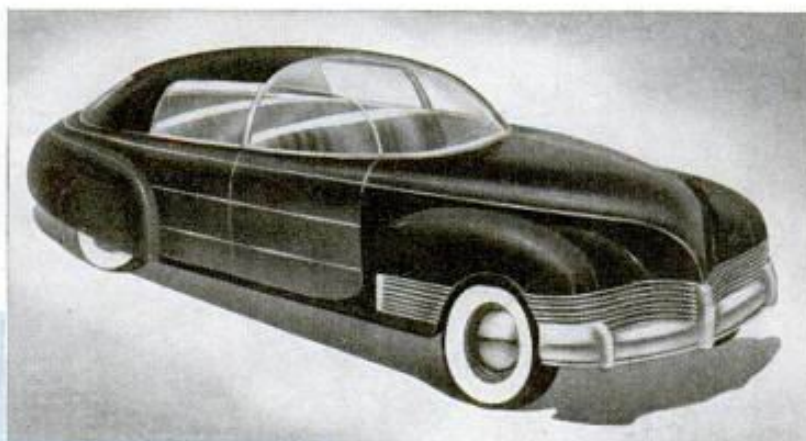
designers, have said: "The destruction and obsolescence of equipment and traditional ideas prompted by the war is a Godsend to us all. It offers the opportunity to start over, with the knowledge and experience of the past and the confidence that we can do for peace what we did for war. We should no longer be handicapped by dated ideas and methods."

Furniture and textiles are bound to undergo changes as molded plywoods and plastics and synthetic fibers have their first chance at peacetime competition. Many of the postwar automobile plans propose woven plastics for seat coverings.

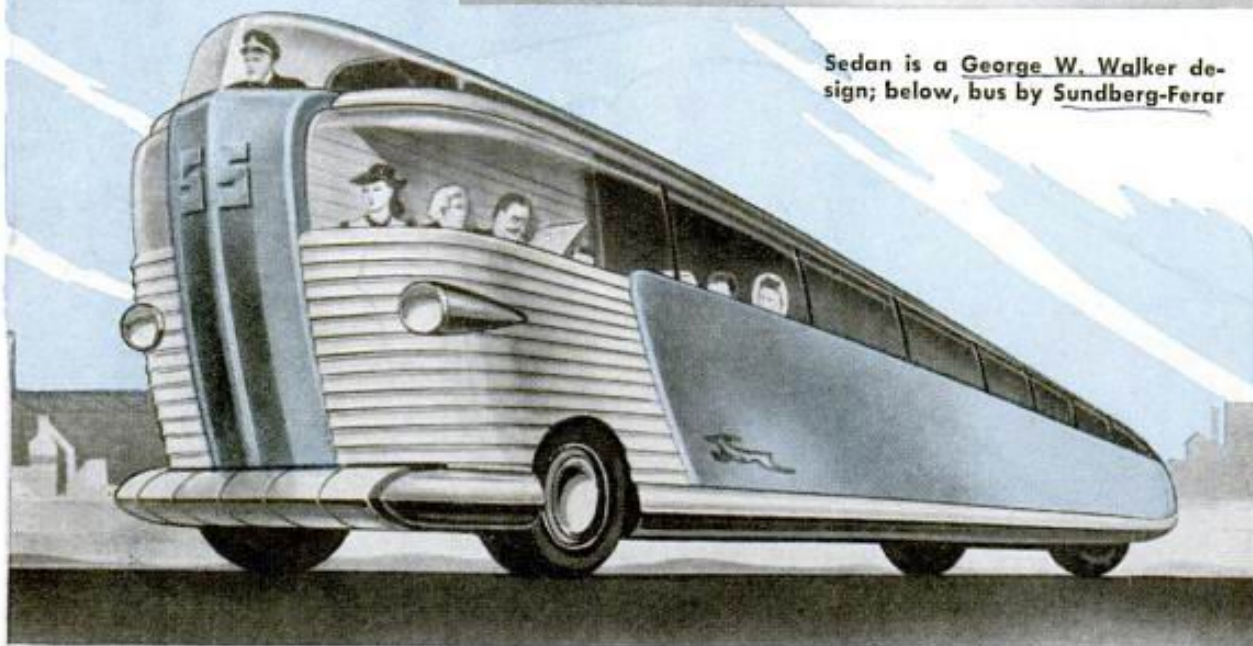
ator with a transparent-plastic corner window, offers a novel suggestion of molded plastic tableware. Modern plastics, he points out, offer an infinite variety of form and color possibilities, and since it is no

Sundberg and Ferar have suggested a plastic chair designed for comfort, its body molded by the "heatronic" method with large presses. Instead of "clumsy steel springs," the designers propose a preformed sponge-rubber cushion and a zipper fastening the upholstery of woven extruded plastic to the chair. The back and legs would be transparent, and the chair would be shaped to support the body at every point.

Brooks Stevens, whose postwar ideas range from a streamline locomotive to a refrigerator



Sedan is a George W. Walker design; below, bus by Sundberg-Ferar





Raymond Loewy styled this proposed helicopter bus, seating 14 passengers, for the Greyhound Corporation

longer necessary to adhere to the traditional round plate form inherited from the pottery wheel, he has molded plates with a modern motif, a straight edge on one side.

Changes in home equipment must be evolutionary, not revolutionary. Old houses have always been the principal market for new appliances, and designers must stay close to tradition to fit the new stove or refrigerator into the old house.

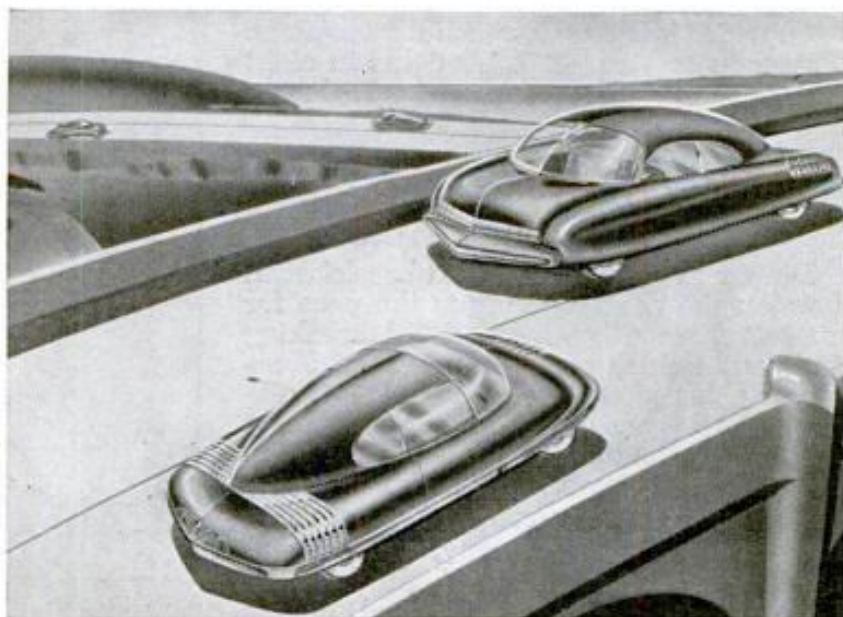
Sundberg and Ferar point out that "universal application of plastics" is a myth.

"Two prime factors will retard the spread of this versatile material into many fields," they say: "dimensional stability and impact strength. Both must be greatly increased, and plastics in general must be greatly reduced in cost if their use is not to be limited to gadgets and ornaments.

"There are, however, three recent developments in the plastic field which do show promise for the future if the cost of production can be made compatible with peacetime economics. One is heatronic molding permitting faster cycles and larger pieces; the

second is the development of a relatively hard and thermostable transparent allyl resin still in the experimental stage; the third is low-pressure molding in which resin-impregnated cloth, paper or plywood can be formed by heat and low pressures."

Money is no object in war. Thus much of the pioneering research that will eventually in the new products and processes of peace has already been charged off. But money is the dictator in peacetime industry. The innovations in store for your new way of living will come gradually as the dreams of the designers prove marketable and economical and sound.



George W. Walker, automotive designer, calls the drawing at right "Highways of Tomorrow"

Ram-wing X-114

floats, skims, and flies



Zippering above the waves at 90 mph, it saves fuel by flying on a cushion of air

By BEN KOCIVAR

When I first saw models and an early flying version of the ram-wing plane in Germany several years ago, I wondered why they didn't simply call it a flying boat. As the pictures on these pages show, it has a hull, it floats, it has an unusual wing, and it flies. But after talks with pilots and designers of the strange-looking craft, I learned that while it is in fact a flying boat, it also is something more.

The ram-wing plane, or aerofoil boat, is designed to fly most efficiently close to the surface. Thus it takes advantage of a phenomenon called ground effect. Such a vehicle can move people and freight over water faster and cheaper than hydrofoil boats or surface-effect ships [PS, June '74] using less fuel than high-flying aircraft.

Land hopping

Aerofoil boats can also fly over land areas where it is not economical to build expensive highways or rail systems; taxi in water like an ordinary displacement boat to maneuver at slow speeds in harbors; and plane at high speed, just touching the surface like a fast hydroplane. The latter technique is useful when visibility is poor, or when it might be necessary to make quicker stops than would be possible if the vehicle were airborne. Takeoff speed for the latest aerofoil design from West Germany

(the X-114) is 40 miles per hour and cruising speed in the ground-effect flight envelope is 90 mph.

What makes it work?

Every time an airplane takes off or lands, its wings build up dynamic air pressure between the plane and the earth's surface, creating a ground effect. The plane rides on a cushion of higher-pressure air. For the aerofoil, this dramatically improves the lift-to-drag ratio by as much as 250 percent. As a result, ground-effect flying requires much less power than flying at altitudes above or out of ground effect. Ground-effect flight also takes much less power than trying to zip along rapidly on the water surface. Ground effect usually becomes evident at altitudes of about half a plane's wingspan. The most desirable altitude, I was told, is about one-quarter the wingspan.

Ground-effect flight is not a new idea. A theoretical study of the concept was developed as early as 1921. And some conventional planes have actually flown with ground effect, at least some of the time. For example, I recall flying seaplanes over the Hudson River with the floats barely off the surface. I would start with power settings that permitted me to make very slow descents from altitude toward the water. Then, as I got into the denser air or the ground effect created by the wing close to the surface, the plane would keep flying effortlessly, never actually touching the water. It was an incredible floating kind of ride.

Extending range

In the 1930's, Lufthansa pilots

flying over the South Atlantic cruised long distances in this surface effect only a few feet above the water. They not only doubled their range but also gave their passengers an extremely smooth flight. During the war, crippled planes used this technique to stretch their remaining fuel and get back safely when their engines could not put out enough power to fly at altitude.

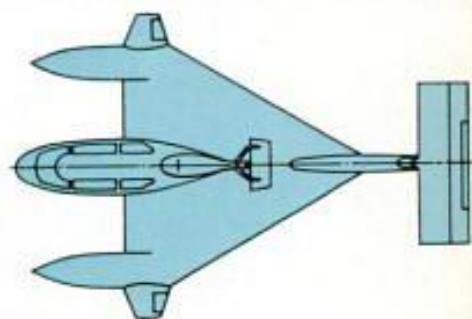
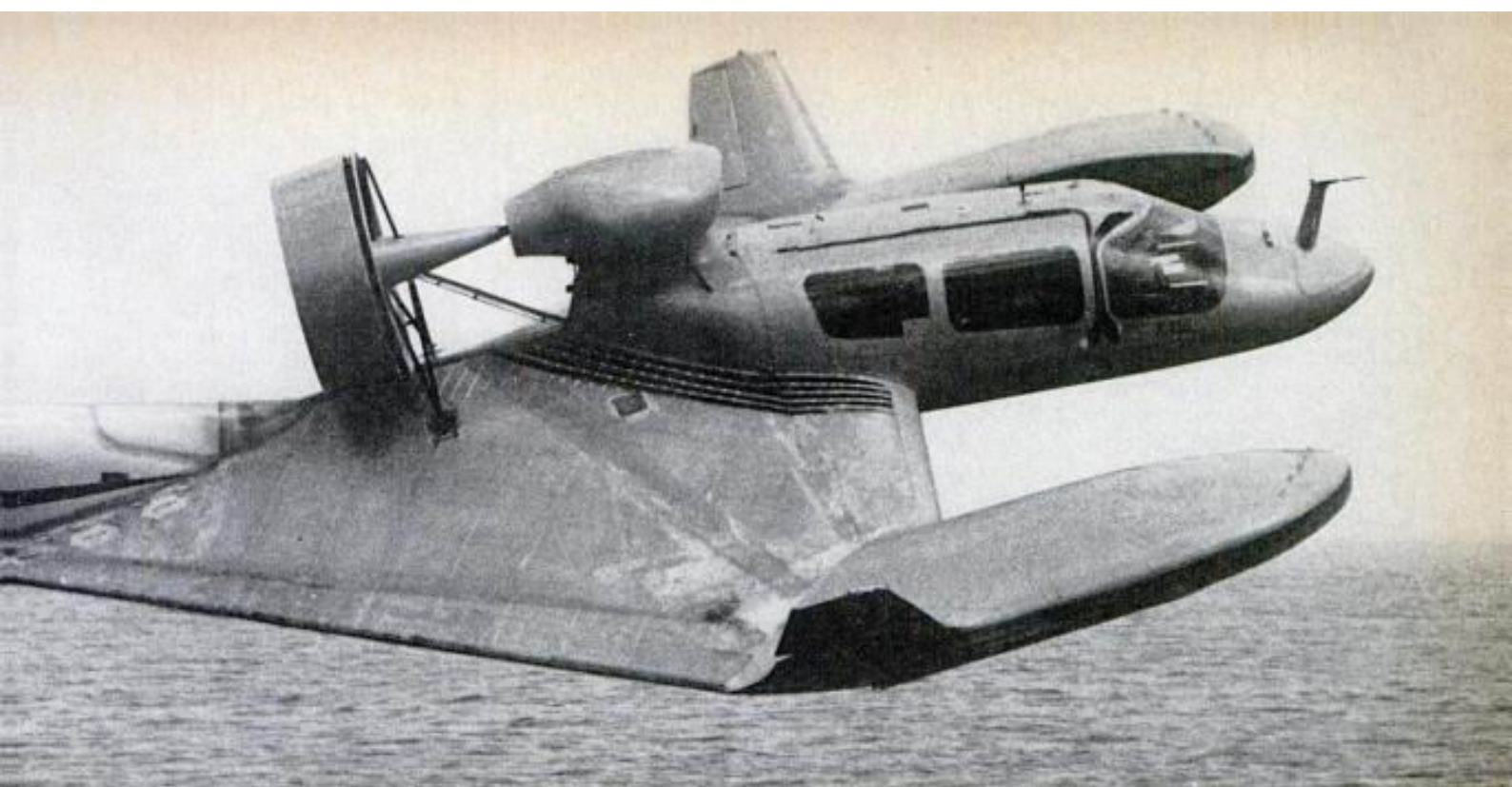
Hanno Fischer, a designer and test pilot for Rhein-Flugzeugbau GMBH who helped build and has flown the newest aerofoil boat, the X-114, told me the craft has a lift-to-drag ratio (L/D) of eight in free flight. This improves to 20 near the ground. Eventually he hopes to achieve 25.

What does this mean in comparison with conventional power planes? "It means we can fly a 3000-pound craft at 70 mph in ground effect with only a 70-hp engine," says Fischer. A comparable conventional plane, such as the Grumman American two-seater Traveler, weighs about 2000 pounds and requires a 150-hp engine for free flight at about 140 mph. Quite a power difference. And quite an additional fuel requirement.

First aerofoil

The career of Dr. Alexander M. Lippisch, who died in Iowa, was long and varied. Born in Munich in 1894, he helped design zeppelins, innovative sailplanes, and tailless supersonic delta-wing planes. He led the team that developed the rocket-powered Me-163B, the fastest military plane in World War II.

Continued



Hovercraft-like plane has a reversed-delta wing (diagram) with a shallow cavity beneath it that provides ground-effect lift at very low heights. Air cushion created during flight enables the X-114 to skim economically only a few feet above land or water. It can leap over low-lying obstacles and also fly like a conventional plane. A pusher prop gives it a cruise speed of 90 mph, with a 1200-mile range. The experimental craft was made in Germany by Rhein-Flugzeugbau.

X-114 flyer: "To jump over a ship, the pilot only has to pull back on the

After the war Lippisch worked for the U.S. Air Force and Navy. In 1959, when he was with Collins Hydrodynamic Laboratory at Cedar Rapids, Iowa, he started developing and flew his first aerofoil boat, the X-112. He conceived it as an "aerodynamic surface-effect, or ram-wing, vehicle," and considered it the best solution for a general-purpose medium-speed transport over waterways. In 1967, the West German Defense Department became interested and awarded contracts for further development. This resulted in the X-113 single-seater and the present X-114, a 40-foot-long seven-seater with a 22-foot wingspan. Current development is being done by Rhein-Flugzeugbau, an affiliate of VFW-Fokker, the same company that is developing the Wankel-powered Fanliner and Fantrainer [PS, March].

I learned some intriguing things about this unusual machine from technical papers and interviews with German pilots and engineers who have flown the plane.

The delta-wing design of the Lippisch aerofoil is most unusual; unlike other delta-wing planes, this one uses the straight side of the triangle as the leading edge, while the other triangle sides taper to the fuselage in the rear. Also, the wings droop dramatically, with float pods terminating the wing tips.

"The reverse delta shape does several things," said Hanno Fischer. "Most important, it provides longitudinal stability. On conventional wings the center of pressure [which provides lift] shifts forward from 45 percent of the chord [or cross section] when the wing is in ground effect to 25 percent at higher altitudes. This shift prohibits practical use of the ram-wing principle for surface-effect vehicles. The reverse delta with negative dihedral [droop] avoids this shift."

Flying high

I had heard that the earlier X-113 had flown not only in ground effect but also at altitudes of up to 2000 feet. How does it get this kind of power?

According to Fischer, the aerofoil needs more power to take off from the water and overcome water drag than it needs to maintain flight just above the water. For normal flight, the engine is throttled back to conserve fuel. Because it has this extra power to get off the water it can also hop up over obstacles such as built-up land areas, low mountains, snow, mud, ice—or ships.

"To jump over a ship, the pilot only has to pull back on the control wheel," says Fischer. "It can hop 66 feet high without trouble. Then you just level out and let it settle back automatically to its former altitude close to the water."

Flying at altitude, of course, requires additional power—and the loss of fuel conservation.

The reverse-delta shape and negative dihedral give other benefits, too. When the boat is in the water, only the small trailing tip of the wing is immersed. This creates much less drag than a conventional delta platform in which the whole trailing edge of the wing would be in the water. At the same time, the negative dihedral makes an immediate "air tunnel" under the wing that gives lift as soon as forward motion begins during takeoff.

The compact delta shape also provides structural advantages. Normally, good lift-to-drag ratios are best obtained by long slender wings like those of high-performance gliders. However, as lift increases, so does induced drag. Because the aerofoil is used in denser ground effect, much of the lift is provided by "pressing" on the ground. This lift, about 35 percent of the total, pays no penalty in induced drag.

Lighter wing

As a result, the aerofoil wing can be a relatively narrow, compact, stronger, and lighter wing providing more lift with less power.

Fischer described another interesting advantage. The aerofoil is absolutely stable. Once the correct altitude has been established, the craft holds altitude automatically—it can be flown hands off. To make landings, a pilot just reduces power

and the plane comes down and flares (levels off) automatically.

The aerofoil is amphibious. Retractable landing gears fold back into the wing-tip floats. These can be lowered one at a time to help make turns when the craft is afloat on the water. There is also a tail wheel. There are no water rudders.

The ducted-fan, 200-hp reciprocating engine of the X-114 has a reversible-pitch prop. Thus the craft can be braked or even moved backwards when it is on the water.

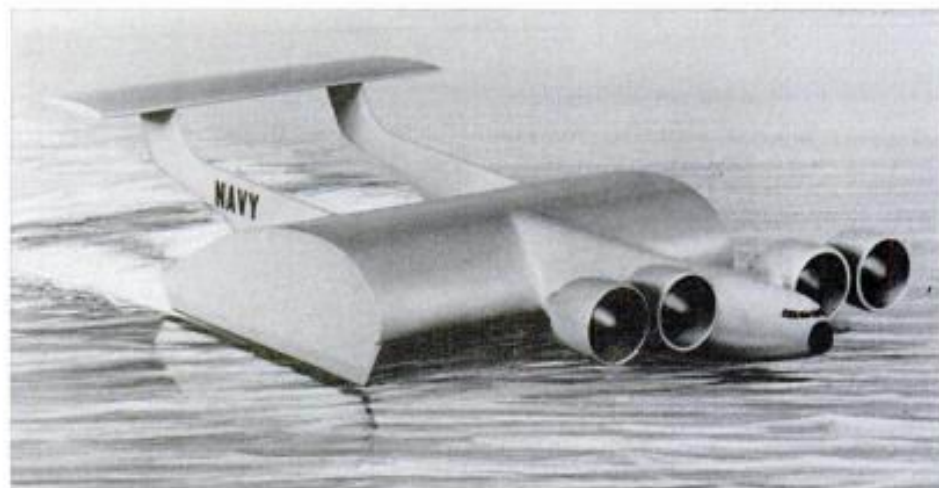
Flight controls are conventional, with dual control wheels and rudder pedals. The instrument panel has one unusual item: An extremely sensitive radar altimeter can measure altitude over average wave heights to within two inches. It can also be set to measure absolute height over the water surface.

Winglet controls

The plane has unusual small winglets that stick up at angles from the wing-tip floats. Although these look like the NASA winglets designed to reduce wingtip vortex [PS, Sept. '76], they are actually the aileron controls used to make turns in flight.

The X-114 is now being tested by the West German Navy in the Baltic Sea, near Kiel. Military interest, beyond straight research, is for possible use of the X-114 as a search-and-rescue craft. The current research program is aimed at flying across the Baltic Sea, where 80 percent of the waves are five feet high, Fischer told me.

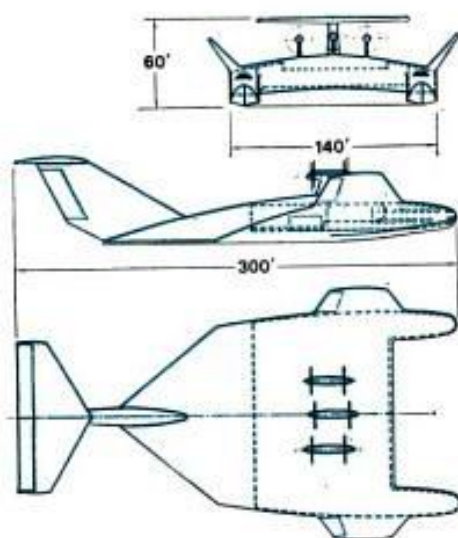
I also learned from Washington sources, who preferred not to be quoted, that although the U.S. Navy is presently pursuing no major active program, it is "keeping



Navy cargo vehicle would rotate the back of its turbofan engines down 30 degrees during takeoff. As it developed for-

ward motion, Lockheed-Georgia's 700-ton design-concept craft would be blown off the water much like a Hovercraft.

craft's control wheel"



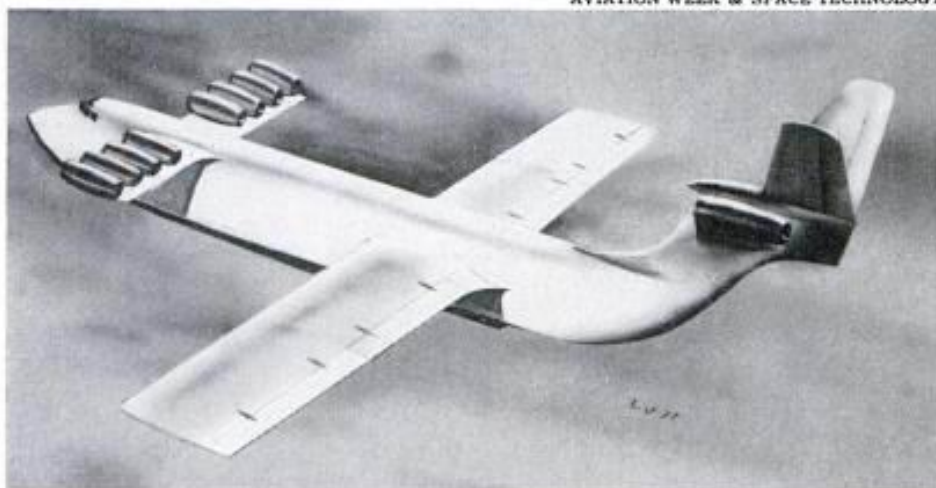
Ocean-going surface-effect ship conceived by the Lippisch Research Corp.

current" on the West German research as well as monitoring Soviet progress on very large multi-engine versions of the aerofoil boat.

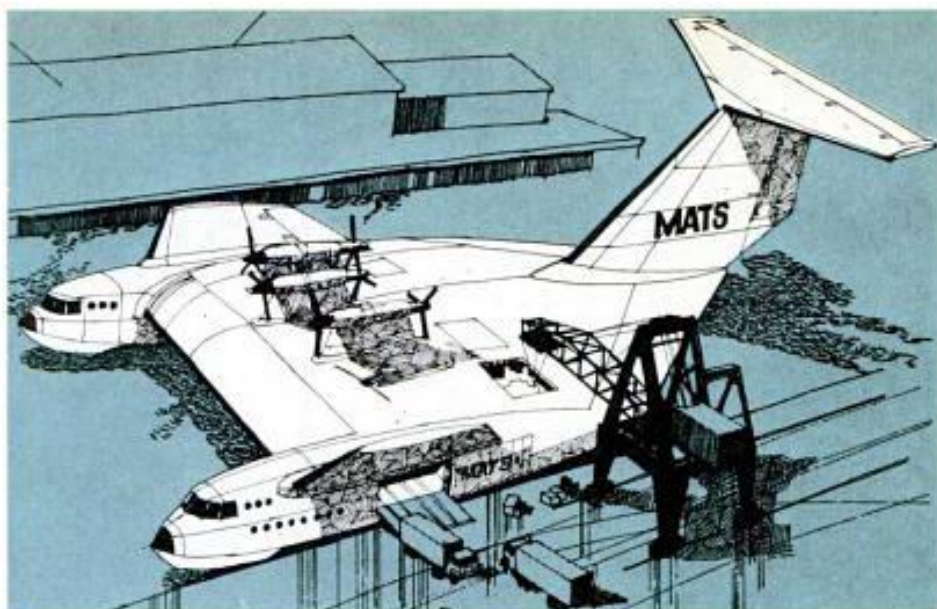
Russia's Ekranoplan

Photos have appeared of early Soviet designs that look like exact copies of early Lippisch models. The Russians are also reportedly flying a large 10-engine, 500-ton experimental "Ekranoplan." One authoritative source estimates that one version of the craft, designed for antisubmarine warfare, could fly 350 mph at 25 to 50 feet over the water.

A sketch of the Russian craft shows eight jet engines that are mounted on a stubby canard forward wing and aimed so that their jet blast hits the water and bounces back up under a big rear main wing. This creates a high-pressure area and provides lift similar to a Hovercraft's.



Russian craft gets lift from air bubble caused by jet blast bouncing off water beneath its main wings. Eight-engine



would weigh 300 tons. Vehicle could carry freight and passengers at low cost

and at speeds several times higher than those of conventional shipping.

Another intriguing design is by Lockheed-Georgia. It's a study for the Navy of a big four-engine turbofan-powered craft. Lockheed has been considering a machine that will weigh 1.4 million pounds, carry a 441,000-pound payload, and cruise 3.8 feet over the water surface at Mach 0.4 (about 300 mph).

The Lockheed proposal, pictured on these pages, is for a huge logistics vehicle to transport large amounts of cargo long distances at speeds much higher than those of conventional surface transportation. This design is for a craft 238 feet long with a wingspan of 108 feet. I was told that no models or smaller versions have yet been made.

The future?

Dr. Lippisch proposed three possible future types of aerofoil boats:

- Small vehicles for sport, recreation, and inland transport missions on rivers and lakes. These would be

AVIATION WEEK & SPACE TECHNOLOGY

one-half to three tons in weight and cruise 60 to 100 mph.

- Medium-size aerofoil boats that would weigh up to 50 tons and cruise at 200 mph.

- Large ocean-going versions of the ram-wing type that could be 1000 tons or more. He predicted that these would not be able to fly high out of ground effect, but could rise to at least half their wingspan. This would enable them to fly over high waves and small obstacles. Their cruising speeds would be about 350 mph.

Military uses of these craft could include fast patrol boats, antisubmarine craft, troop carriers, or landing craft.

How about civilian uses?

Originally, the ground-effect plane was proposed for relatively undeveloped areas. In the few short years since Dr. Lippisch got his project off the water, however, we have run head-on into the energy and fuel crisis.

Stretching fuel

The supersonic Concorde is running into serious opposition because it uses a lot of fuel per passenger—even though it saves considerable chunks of time. Airline companies and aircraft manufacturers are worried about the rising prices of fossil fuels and are hoping for fuel-saving designs and engines. It is no secret that the aerofoil concept has been on the back burner for several years. With the obvious need to stretch the world's limited fuel reserves, however, this concept of going farther on less fuel by flying closer to the ground may soon get more urgent consideration by aircraft designers. **13**

aircraft was reportedly tested in 1974; newest versions, suitable for antisubmarine warfare, may go 350 mph.

DECEMBER 1977 \$1.00

Popular Science

The **What's New** magazine

DAMADIAN'S SUPERMAGNET

How he hopes
to use it to
detect cancer

Ram-wing X-114

floats, skims, and flies



How 914-MPG CAR won
super-mileage contest

Big sound from those
new MINI-SPEAKERS

New DIGITAL WATCHES
do more than keep time

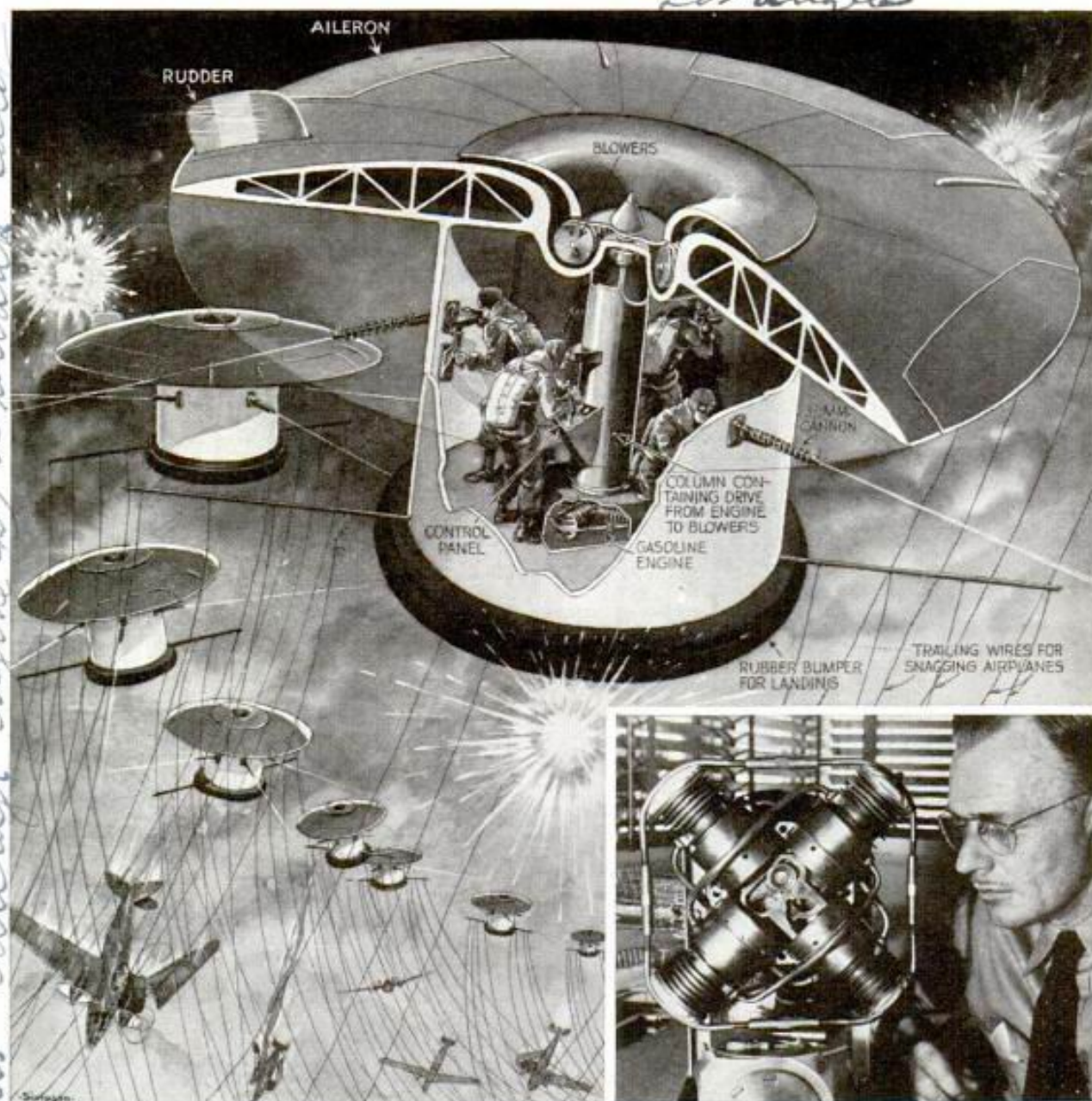
SOLAR PONDS: heat
from a hole in the ground

PS guide to
FIRE EXTINGUISHERS

Your car: a pro tells you how
to make BODY REPAIRS

2661. Capt. Thomas & Stinson Jr.
3872 Franklins
Los Angeles

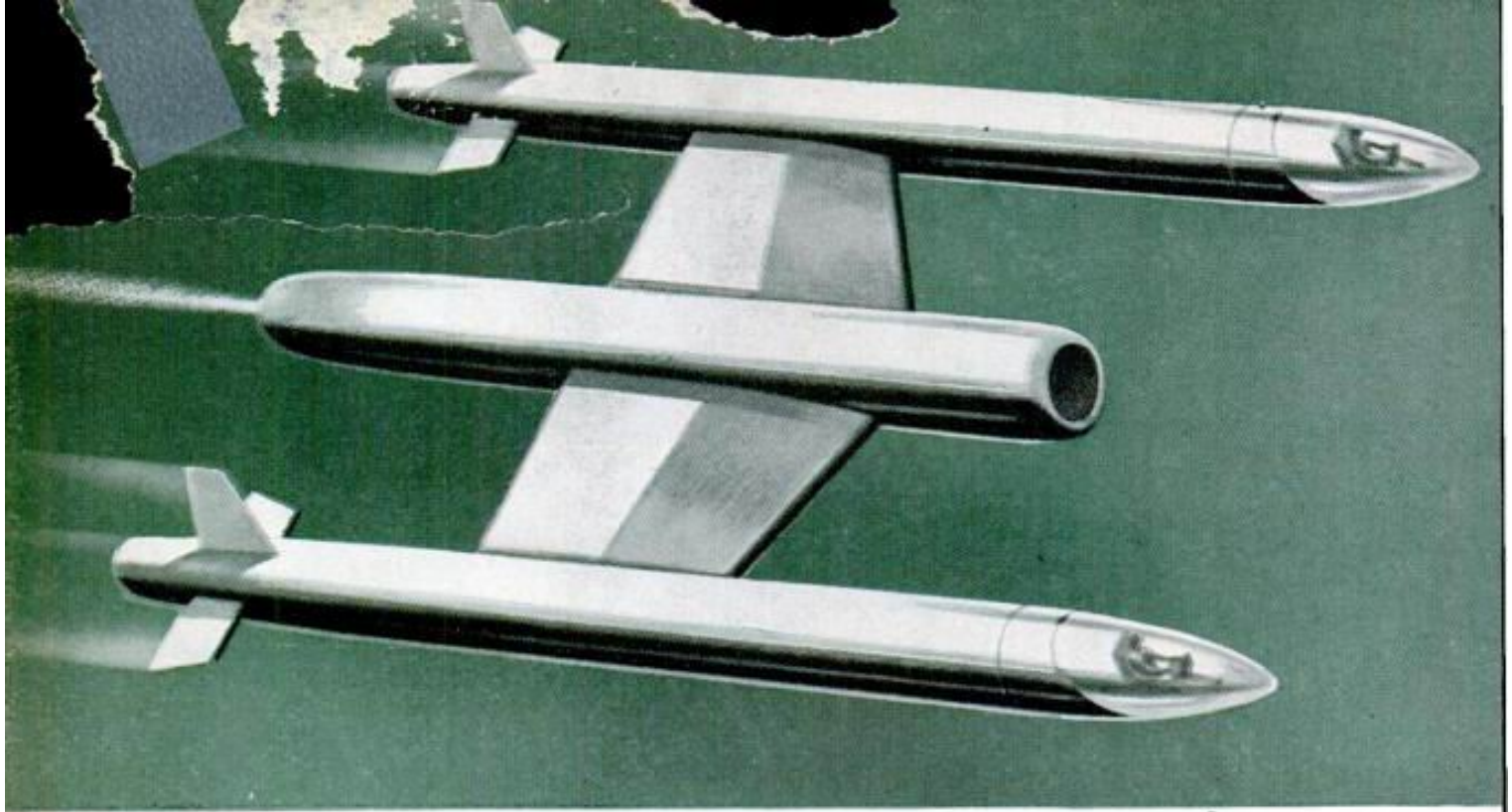
"Flying Mushroom" Planned as Aerial Pillbox



The drawing shows "flying mushrooms" trapping bombers in trailing wires and gunfire, sectional view indicating how air is drawn in, then blown over wing surface. Right, working model of 80-hp. rotary engine

Propellerless aerial gun turrets that could fly straight up at 70 miles an hour are proposed by a California aircraft inventor as a novel means of air defense. Already his "flying mushrooms" have proved satisfactory in scale-model form and a full-scale demonstration is being planned. The top of the "mushroom" is a circular wing, its outer circumference the thin "trailing" edge. The "leading" edge surrounds a central hole, a conical pit into which air is drawn down by powerful blowers and then discharged radially over the upper surface of the wing. This creates lift just as it is created in a conventional

airplane. Movable control vanes on the wing surface would prevent the craft from spinning and would facilitate maneuvering it. By proper manipulation it could be made to travel horizontally as well as vertically, dodging attacking aircraft. The stem of the "mushroom" would house a crew of three or four men and a battery of 37-millimeter or even larger guns, firing at the enemy through portholes in the armored wall. Efficiency claimed for the design is so high that an ordinary automobile engine could power the blower to lift the loaded aerial gun turret and its crew. For even higher efficiency the inventor, Charles



Artist's conception of a supersonic airplane with large center ram-jet. Pilots sit in front of twin fuselages, which are equipped with rocket engines to supply auxiliary power if the ram-jet engine fails.

been done (PSM, Oct. '46, p. 121), but we still have a long way to go before pilots can open wide the throttles of the supersonic planes already here, like the Bell XS-1 and the Douglas Skystreak. The Navy, the AAF and civilian researchers are all working at top speed to prepare the man for the machine.

The cockpit for the supersonic pilot will

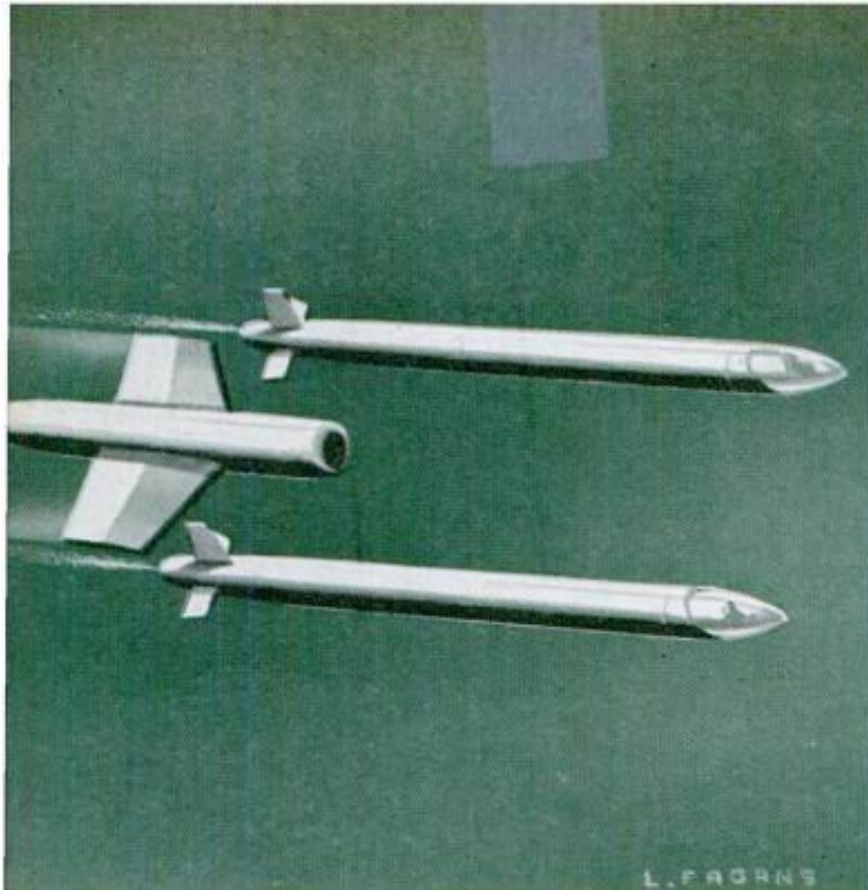
"Mach cones," opaque shock waves at supersonic speed, may require instrument flying even in clear weather. Special optical devices may also be needed.



be pressurized and refrigerated against the terrific heat created by friction. It will also be soundproofed, not only to eliminate the roar of rockets and ram-jets, but to protect the flier against ultrasonic vibrations and noises above the range of hearing to which his brain centers and glands will be exposed.

Another problem is the matter of G (unit of measure of pull in any direction; the normal weight of an object or person is one G). Should the power plant of a plane flying at 1,500 miles an hour fail or lose speed, the deceleration to a coasting speed of 500 miles an hour, at the most, would be terrific. With the sturdiest seat and safety harness to hold the pilot's body firm, he would literally explode as everything inside him kept going when the plane and body stopped. One test pilot has predicted that the deceleration of a supersonic plane might involve forces as high as 100 G.

The photographs on page 137 clearly show what this would mean. These pictures, part of a report by Charles Code, Earl Wood, and Edward Lambert of the Mayo Clinic, vividly indicate what happens to a man at only 3G. They explain why a supersonic pilot must have some auxiliary power plant to continue motion if the main source of power should fail or suddenly slow down



If the plane's speed falls below safe limit, jet and wing section is jettisoned and rocket engines cut in. When the fuselages slow to safe speed, pilots pull levers to release capsule noses, then open their 'chutes.

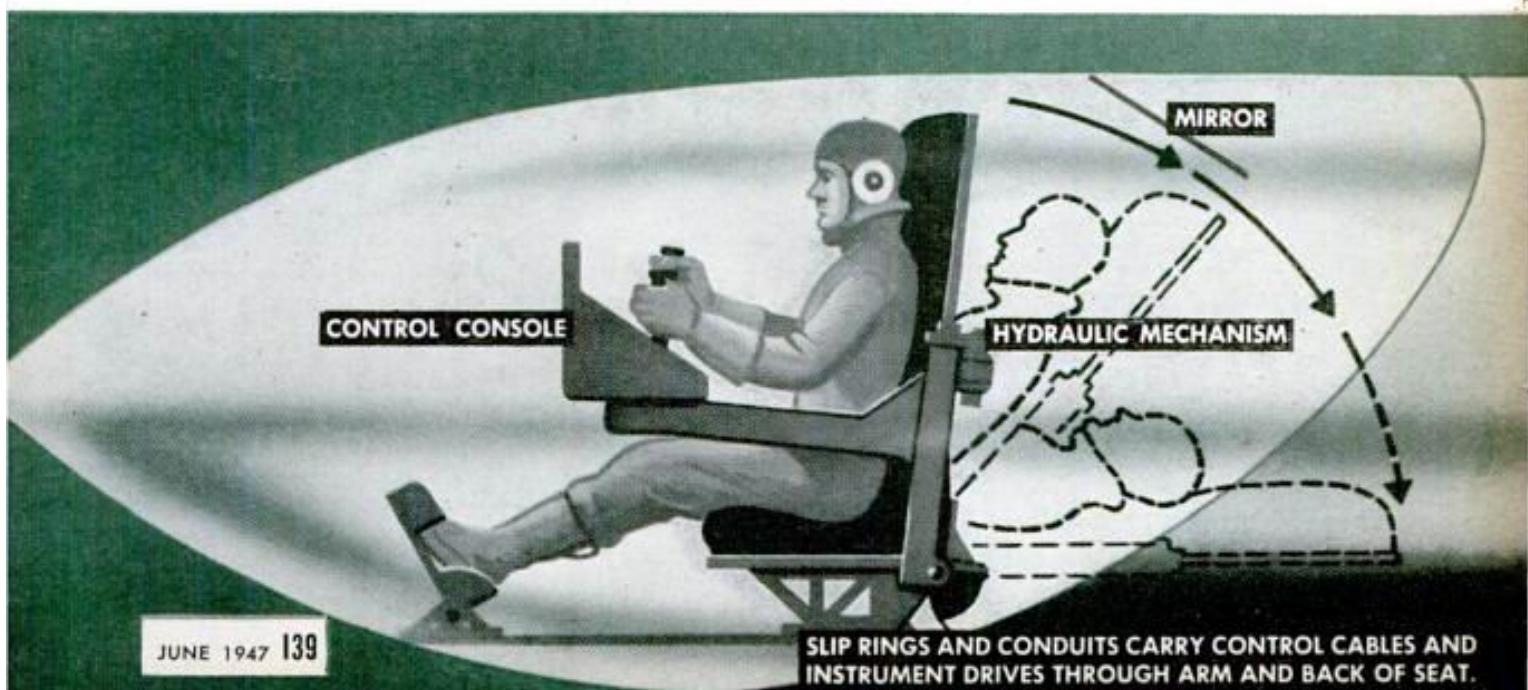
for any reason, enabling him to decelerate at a slower rate until he reaches a speed at which it is safe to parachute.

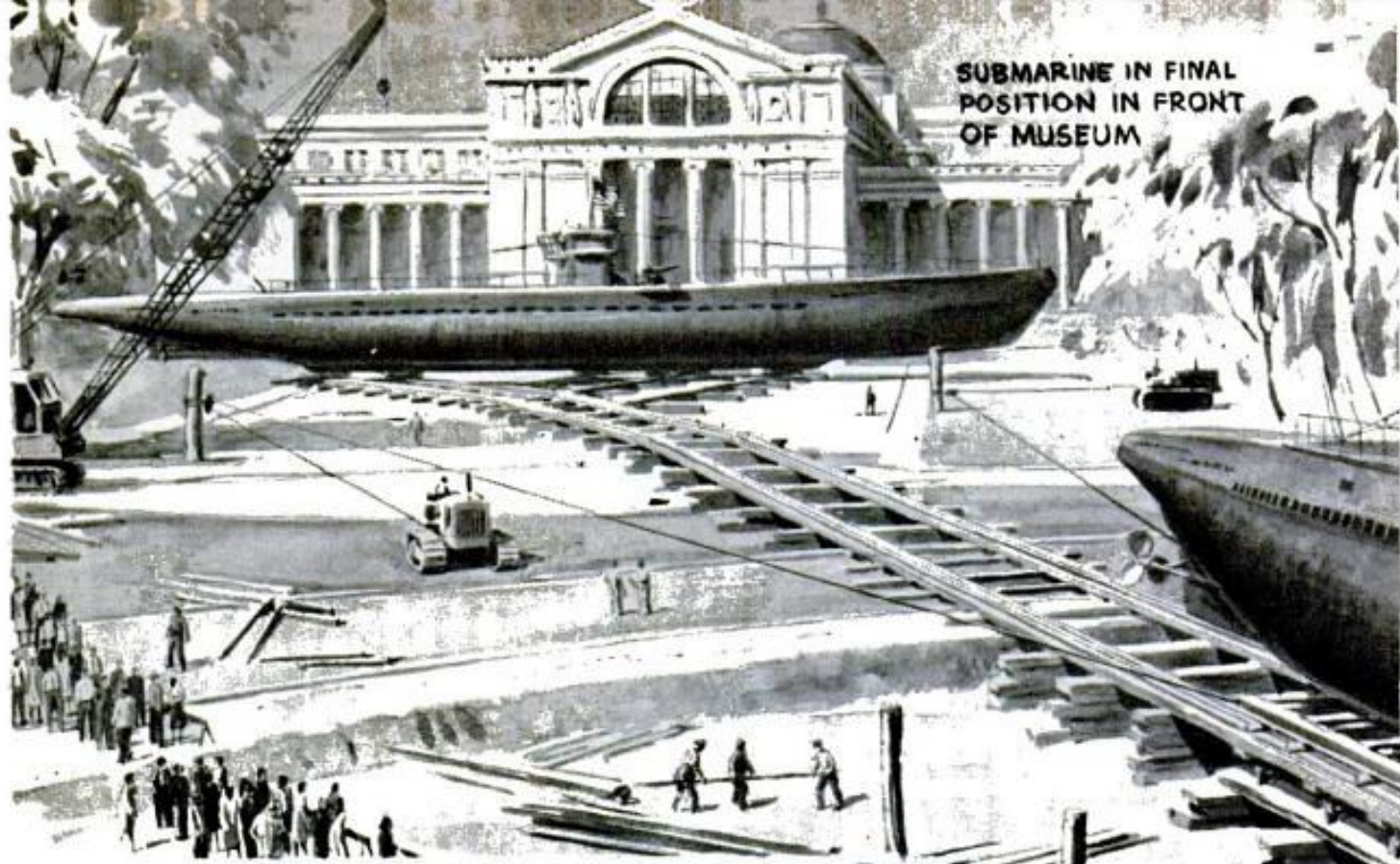
In addition to speed and sharpness of maneuvers, bodily position is also related to the effect of G forces. Experiments have shown that by lying prone, a pilot can take twice as many radial G (in turns and pull-outs) without blacking out. The force is directed through the shortest, strongest part of the body instead of traveling the airman's

whole length. In the Northrop XP-79 flying wing and in an experimental Navy plane the pilot flies prone.

The prone position, however, is not healthy when lateral G is exerted by suddenly speeding up or slowing down. To solve this problem, the Navy has devised an automatic reclining seat. The flier sits upright during straight flight and lies supine during turns and dives. Thus, the position of the body is automatically changed so that

Automatic reclining seat protects pilots from effects of high G forces by changing position of the body.





SUBMARINE IN FINAL POSITION IN FRONT OF MUSEUM

HOW SUB WILL BE LOADED FOR FINAL RIDE



- 1 SUB IS FLOATED OVER SUNKEN DRY DOCK BY FILLING GRAVING DOCK ABOVE LAKE LEVEL.



- 2 WATER IS PUMPED OUT OF BIG GRAVING DOCK, LOWERING SUB ONTO SMALLER DRY DOCK.

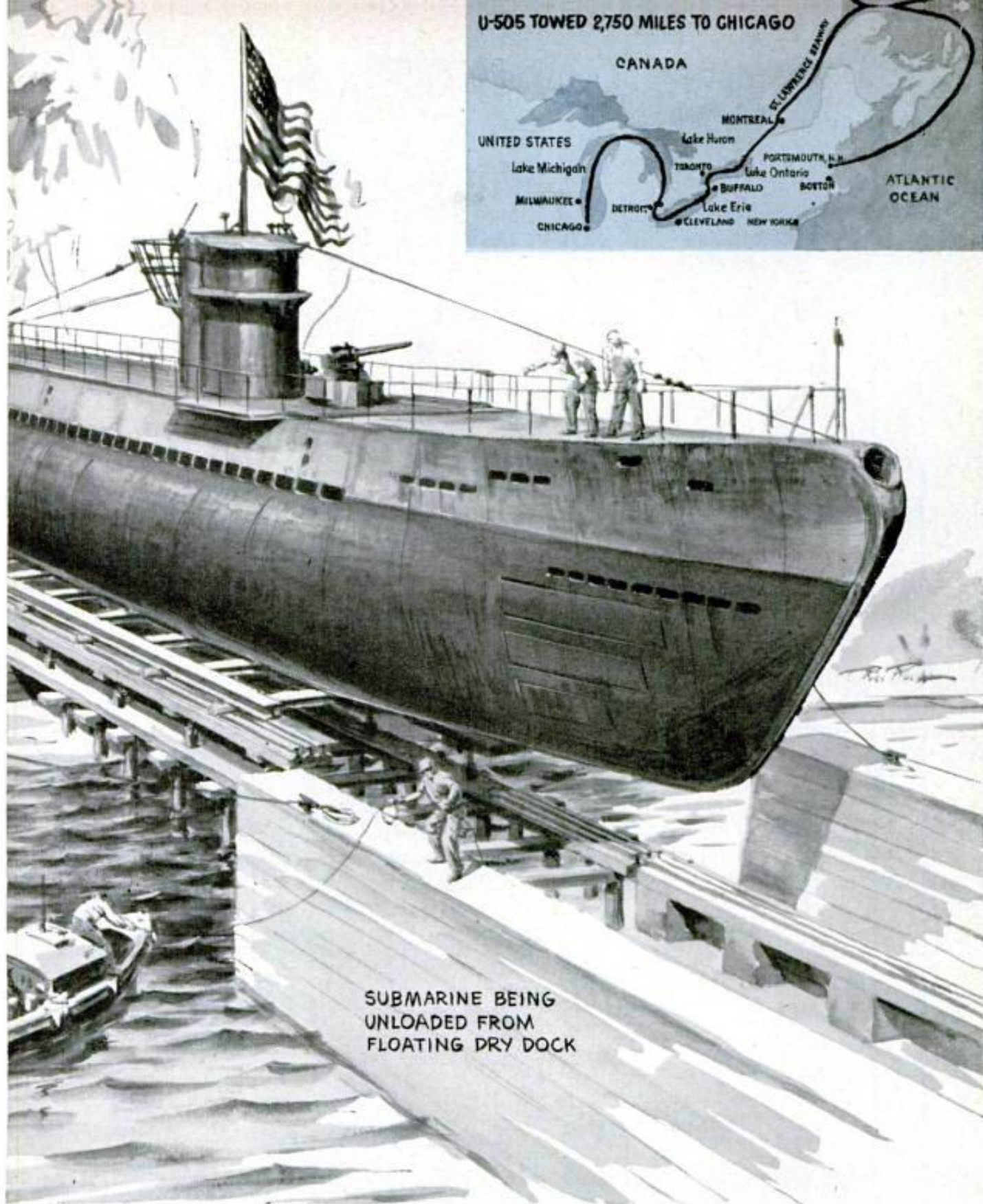


- 3 LAKE WATER IS LET INTO GRAVING DOCK, AND DRY DOCK RISES AS A BARGE FOR TOWING.

They're Parking a Submarine

THE only submarine ever captured on the high seas will come to final anchorage this month high and dry in Chicago.

There, on July 4, the former German U-505, seized by a boarding party of U. S. sailors during the Battle of the Atlantic, will be dedicated as a memo-



rial to Americans lost at sea in World War II. Public subscriptions are paying for the \$200,000 moving job.

Towed to Chicago by the inland water route mapped at upper right, the U-505 will be loaded aboard a floating dry dock, as shown at lower left, for beaching on the shallow shore of Lake Mich-

igan. The larger sketch shows the plan worked out by a retired house-moving engineer, Seth M. Gooder, for the tricky final operation: hauling the 252-foot, 920-ton craft ashore and parking it in concrete cradles as a permanent exhibit at the Chicago Museum of Science and Industry.

Tapping the oceans' vast energy with undersea turbines

Time: the mid-'80's. Place: the swift-moving deep-blue waters of the Florida Current. Tethered to the ocean floor, a huge ducted turbine floats well beneath the surface, its twin rotors lazily spinning in the flow of a massive stream and driving an electric generator. This scene, depicted on our cover, is not fantasy.

To explain the evolution of the "Coriolis concept," we asked one of its developers, P. B. S. Lissaman, to write this story. No stranger to readers of PS, he helped design the history-making, man-powered aircraft Gossamer Condor and Gossamer Albatross [PS, Jan. '78 and Dec. '78]. Vice-president of AeroVironment Corp., Dr. Lissaman is an Associate Fellow of the American Institute of Aeronautics and Astronautics. — The Editors

Watermills in the Gulf Stream and other powerful sea currents could produce electricity economically

By P. B. S. LISSAMAN

Anyone who has dealt with the oceans, which cover 60 percent of our globe, cannot avoid being impressed by the mighty and magnificent power of the sea. Constantly in motion—flowing, flooding, ebbing—the oceans are the major receptor of the sun's daily energy flux, processing and storing this virtually limitless source.

Among the greatest reservoirs of solar energy are the ocean gyres, or circulating current systems, generated by the prevailing global winds. The

energy density in these currents is very high, because they are created by a twofold intensification of the direct sunlight: first by the transformation of the sun's heat into wind, then by the transfer of the surface wind stress into the wind-driven currents. This intricate energy transfer is part of the mighty global heat engine. In the Northern Hemisphere, the gyres rotate clockwise, and because of the Earth's spin, are strongest on the western shores of the oceans.

In 1835, Gaspard Gustave de Coriolis published a paper setting up the basic equations describing the distortions of fluid motions due to the Earth's rotation. It is this phenomenon, today called the Coriolis Effect, which intensifies the western portion of the North Atlantic gyre—the Gulf

Continued

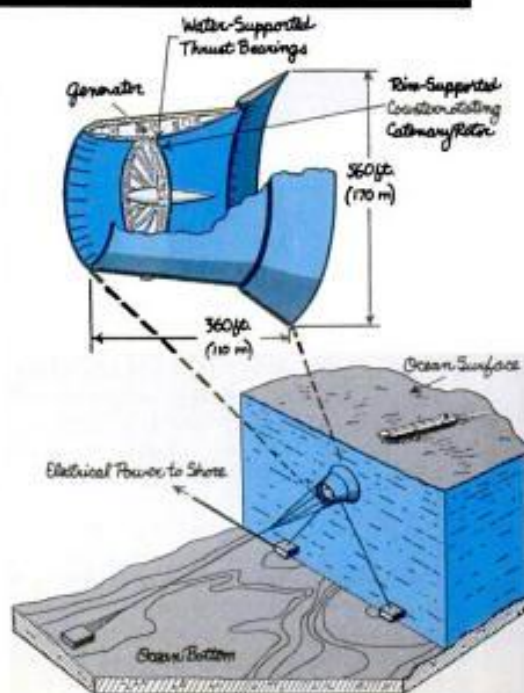
Generating electricity with a Coriolis turbine

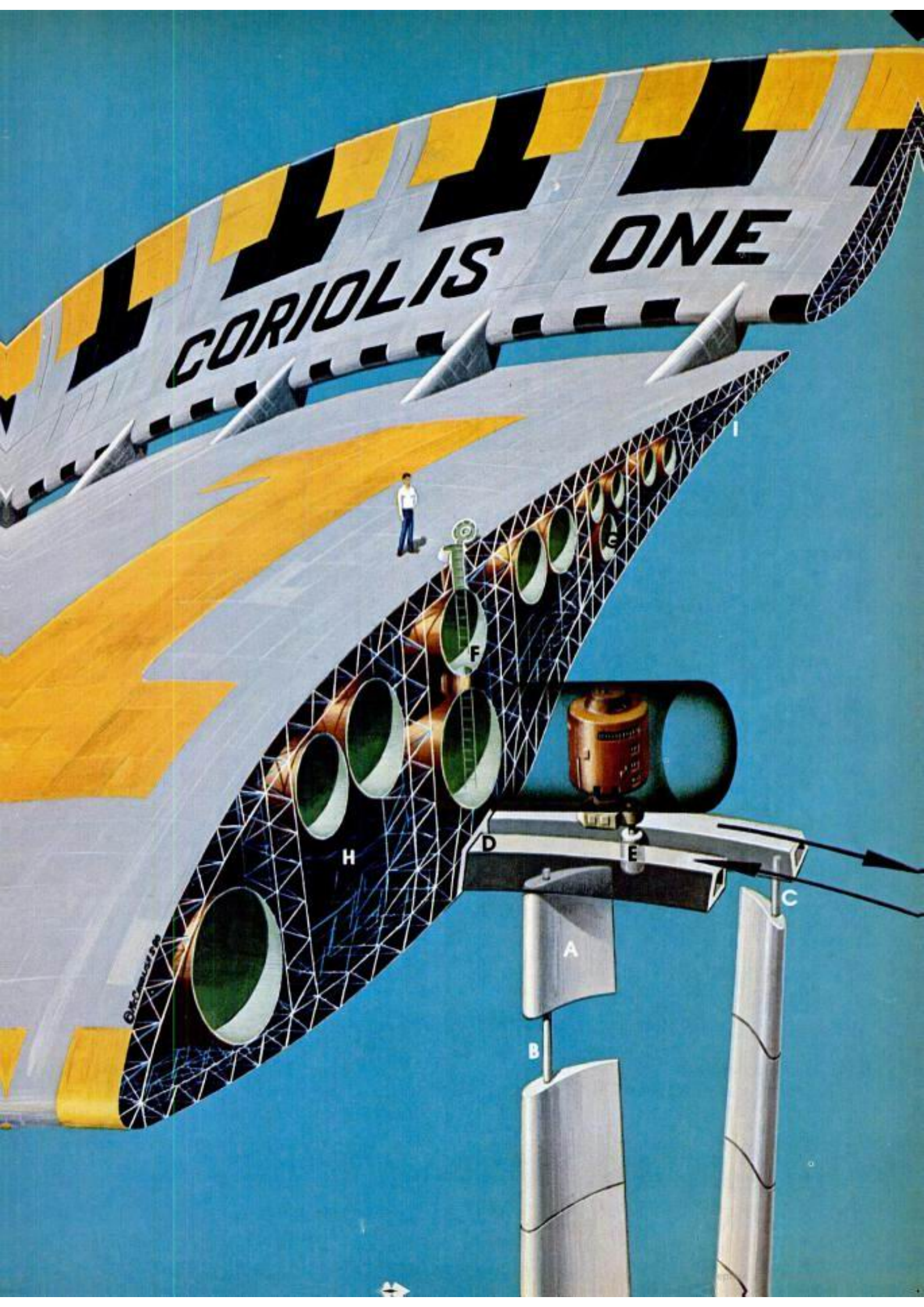
The giant turbine would first be towed in a half-submerged mode to a designated site in the Gulf Stream or other high-energy-density current. Coriolis would then be lowered beneath the surface, by adjusting its buoyancy, and moored to sea anchors on the ocean bottom (see sketch, right). The turbine's general configuration is shown in the sketch and in the detailed cross section (painting, opposite page).

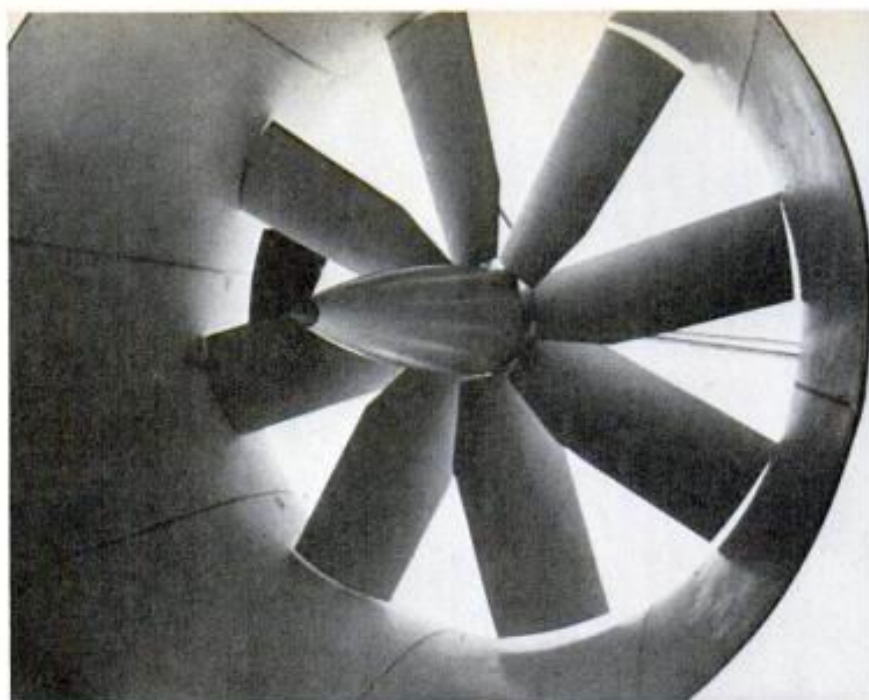
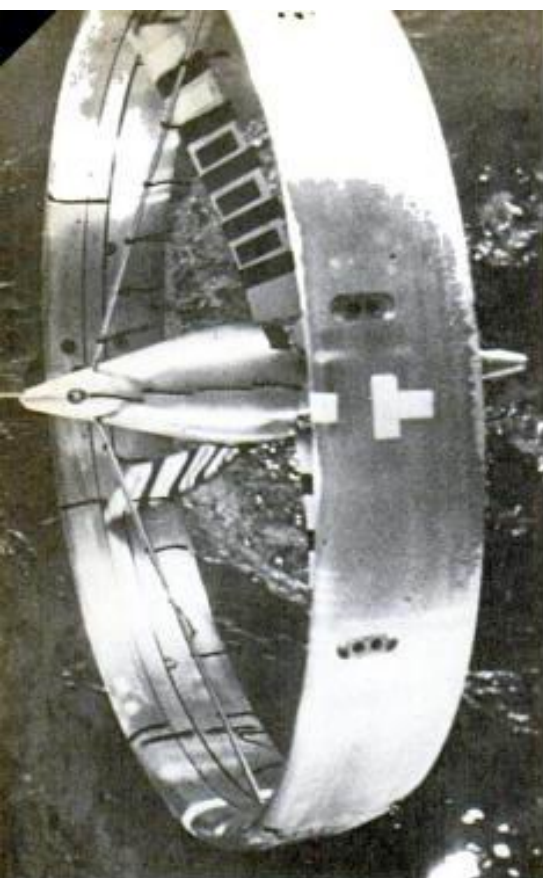
The central mechanism of Coriolis is a two-stage turbine, with two counterrotating rotors. The rotor blades consist of segments (A) threaded along a flexible cable (B) made, perhaps, of Kevlar. In a current stream, the floppy blades assume the shape of a catenary (the curve formed by a rope supported only at the ends). The specially designed shapes of the two sets of segmented blades force them to take opposite-angled orientations with respect to the water flow. Therefore they develop thrust and turn in opposite directions,

driving two counterrotating, circular rims (C), which ride in a water-supported thrust bearing (D). The rims turn friction drives that are connected to electrical generators (E) inside the flared duct shrouding the rotors. The duct also houses control equipment, pressurized access tubes (F), and ballast tanks (G) for altering buoyancy (needed during towing, lowering, and raising the turbine for maintenance). Generally, the hull is flooded (H). The hull structure itself is a space frame truss (I). The hull also provides attachment points for the mooring system. The flared, slotted duct increases the energy of the water flow considerably, and thus augments the power output of the unit.

Electricity generated by the Coriolis turbine is sent to shore over high-voltage DC submarine cables and is inverted there. A unit of the size shown, moored in the Florida Current, could have a rated power output of 83 megawatts.







Coriolis design stages: Small ducted rotor, above, designed by David Thompson, was mounted alongside power boat and tested at various speeds. Results proved

ducting enhanced output. Later, a catenary rotor, left, was tested at David Taylor Naval Ship Research and Development Center, proving stability of design.



Gulf Stream system includes Florida Current, is part of North Atlantic gyre. Twenty miles off Miami Beach, Current contains 50 times more energy than world's rivers.

Stream system—so that the Florida Current, flowing northward only 20 miles (32 km) offshore of Miami Beach, contains 50 times more energy than all the rivers in the world.

For many decades visionaries and technologists have dreamed of using this power. Now the concatenation of oil scarcity, escalating global energy demands, and mounting petro-political instabilities, coupled with the mighty capability of modern engineering, has made this goal appear attainable.

Inspiration on a levee

William J. Mouton is a charismatic personality, a registered civil engineer and professor of architecture at Tulane University in Louisiana. Bill combines his knowledge and love of the old and intricate wrought-iron fabric of the French Quarter of New Orleans with a progressive and pragmatic vision. The result can be seen in his design of slender, steel space

frames for giant contemporary structures, and in his active consulting work in creating innovative concrete and steel towers for the offshore oil industry. A former naval aviator and a dedicated and expert sailplane pilot, Mouton is obsessed with the power of the elements and the harnessing of their natural energy.

In 1973, standing on the levee in New Orleans, watching the roiling, turbulent flow of the flooded Mississippi, he, like many before him, started thinking about the prospects of producing energy from hydroelectric turbines mounted under barge-like platforms moored in the river. But the Big Muddy seemed too small, too capricious. Seeking a more energetic and reliable source, his visions turned to the Gulf Stream, that mighty river in the ocean, always in flood, always streaming northward.

Mouton is a man who views the world on a large scale. He envisaged huge ducted turbines—many of them, each larger than a football stadium—submerged in the North Atlantic.

He could handle the hull and mooring—it was standard marine engineering of the sort embodied in many structures of his already in the Gulf. But he needed a rotor expert. David F. Thompson, President of TM Development, Chester, Pa., was a natural choice to develop the novel rotors for this yet unnamed concept. Dave Thompson is an individual engrossed in new technological ideas and novel ways of using advanced materials. A widely experienced rotor and propeller designer, his corpora-

tion manufactures the only certified lightweight advanced composite turboprop aircraft propellers.

Mouton and Thompson developed the first patentable ideas, and then sought financial backing. This was provided in 1975 by Walter Hajduk, an industrialist of Pennsauken, N.J., who formed Hydro-Energy Associates to finance and direct the program. While Mouton was designing a large ocean turbine unit, of about 560 feet (170 meters) diameter, Thompson built and tested two small three- and 4.5-foot (0.9 and 1.4 m) ducted-rotor units. These were instrumented, mounted alongside a powerboat and tested at a range of speeds. The turbine went round. The output was measured. The duct did provide amplification of the energy flux. The system worked. Design of the large unit progressed.

This first 560-foot unit was designed to develop a power of about 83 megawatts in a current speed of about 4.5 knots (2.3 meters per second). First studies of the energy of the Florida Current had indicated there was a central core, about 16 miles (26 km) in lateral width and extending from the surface down to about 750 feet (230 m), where the annual average speed (the energy speed) was about 3.7 knots (1.9 m/s). It varied from a peak of about 4.5 knots in midsummer to a winter low of about 2.9 knots. The summer high output matches quite well with normal Florida power demands, which tend to be higher during the hot months.

The mechanical and hydrodynamic

To be built by M. Freyssinet
on Mont Valerien hill.

S.W. POPULAR MECHANICS

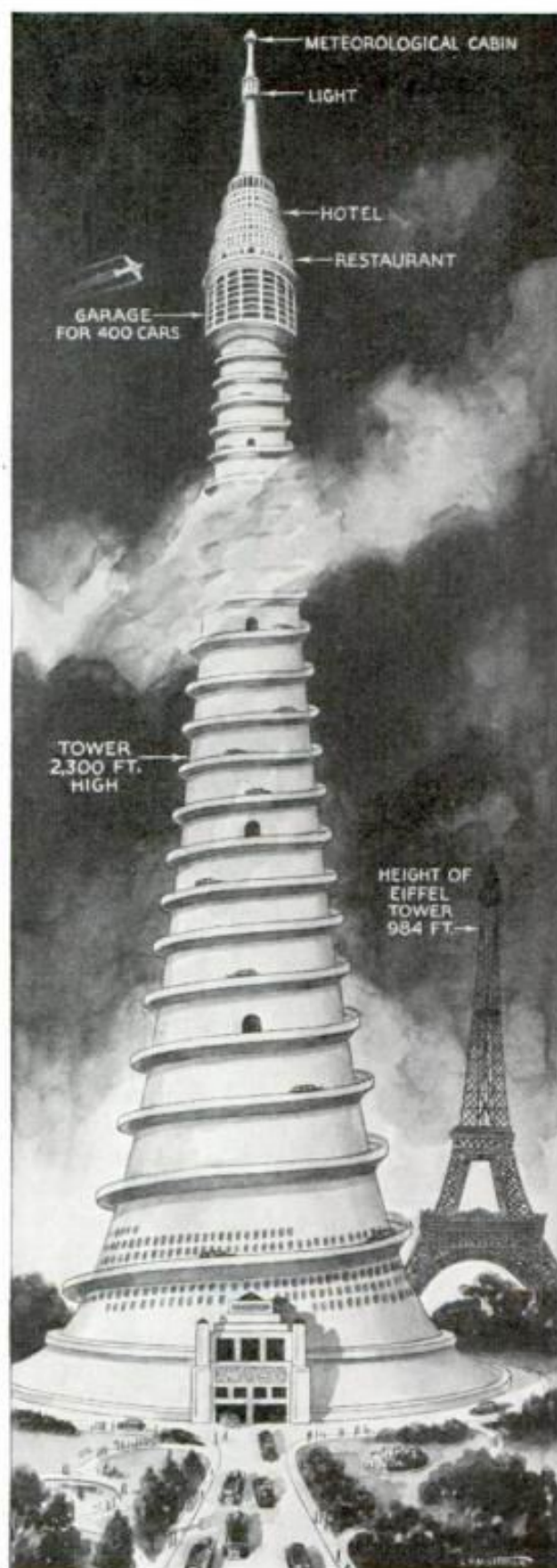
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TOWER NEARLY HALF MILE HIGH TO HAVE A SPIRAL ROAD

One of the features planned for the Paris Exposition of 1937 is a mammoth tower of concrete, 2,300 feet high, up which motorists can climb in their cars. The motor road, three and one-half miles long, would spiral around and around the tower to a height of 1,640 feet, where a garage accommodating 400 cars would be situated. Above the garage a restaurant is planned and above that a hotel several stories high. On top of the hotel a lofty pillar would support a powerful aerial beacon, and a cabin for meteorological observations. Cars ascending the great spiral ramp would travel under their own power, but in descending, they would be attached to a monorailway, the driver steering the car while the speed is controlled by the monorail attachment. From the ground the beacon, it is estimated, could be seen for 160 miles, and it could be observed from an airplane over England. The site for the tower is a hill 500 feet high, on the outskirts of Paris.

INVISIBLE ENERGY IN NIGHT SKY FOUND BY SPECTROSCOPE

Even when the night sky appears inky black to the human eye, it is a luminous power house of energy under the spectroscope. This sky energy is not starlight, according to Dr. V. M. Slipher, director of Lowell observatory, Flagstaff, Ariz. Part of it is an aurora which the eye never sees. The rest comes beating down ceaselessly upon the earth, possibly from space. As revealed by the spectroscopic "eye," there are really three auroras. One is the well-known visible display so often accompanied by magnetic storms. The second, although never seen, is permanent. The third comes briefly, flashing on just after sunset and just before dawn. Its arrival is the moment when the last rays of the sun, or the first, touch the earth's atmosphere directly above the observer's head. Doctor Slipher has named these light emissions "cosmic radiations," which should not be confused with the cosmic ray. Dr. Henry Norris Russell, of Princeton University, says these radiations probably originate in the extremely rarefied upper layers of the earth's atmosphere,



Proposed 2,300-Foot Tower for Paris Exposition; It Would Be Circled by Spiral Motor Road

which reflect radio waves and make it possible to send messages around the world.

Denver Post 4/23/33
NY Times 4/23/33

Under-hill village

tames a plunging slope

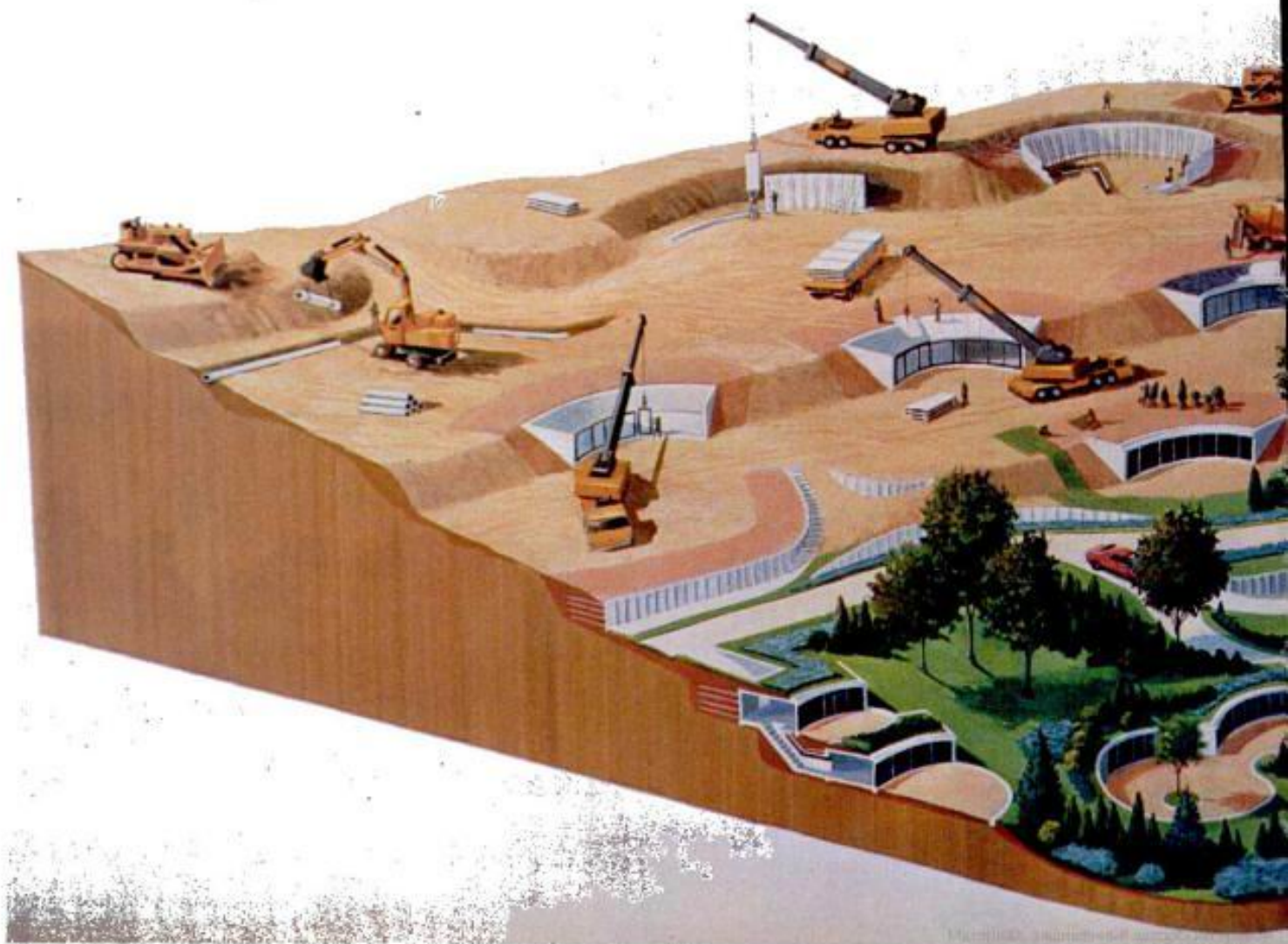
This construction method lets you tuck houses into hillsides too steep for conventional development

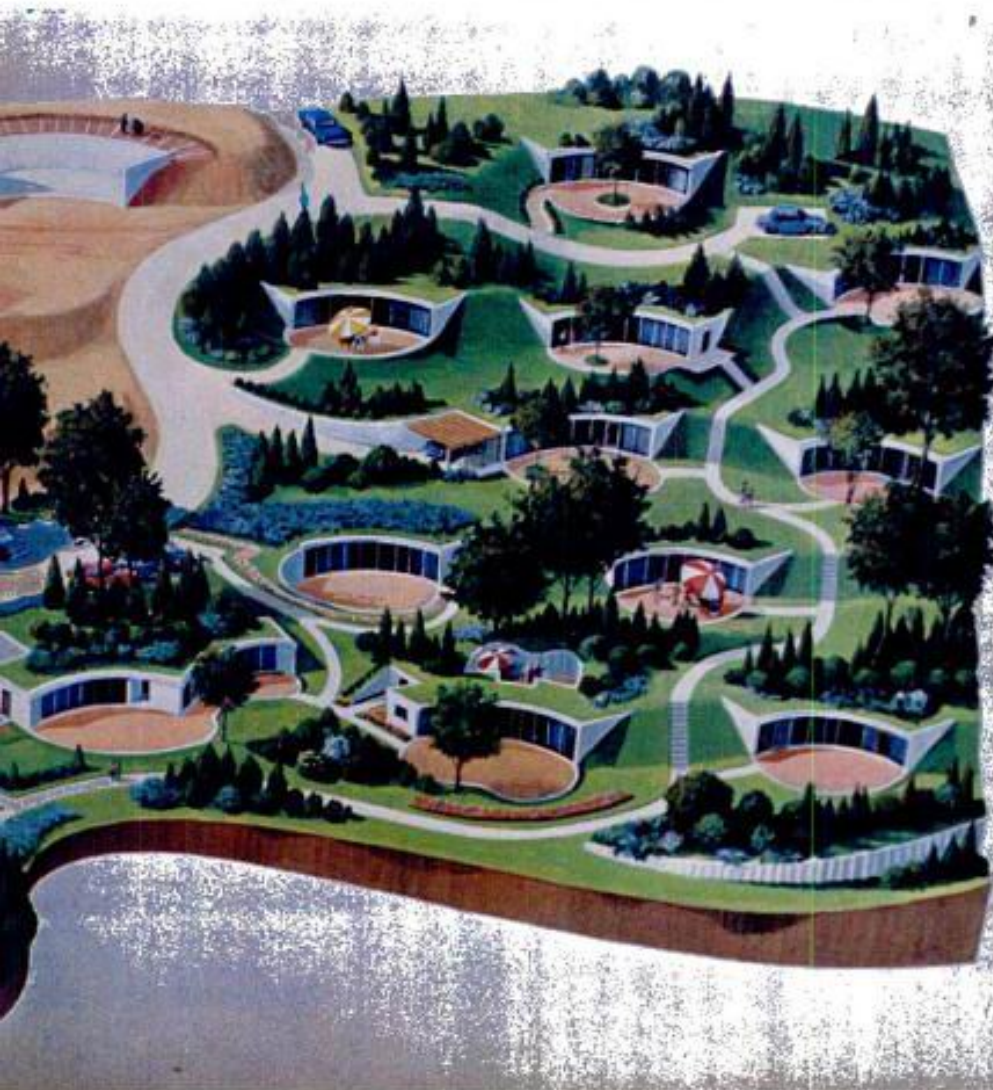
By V. ELAINE SMAY

Drive a short way north from Nice, on the French Riviera, into the foothills of the Maritime Alps, and you'll find yourself in a lovely landscape of steep green hills, carefully terraced in places like some giant's staircase. You turn off the main road onto a spur that descends down the hillside. To

your surprise you drive past a house. Then another—and another. From above you could see only the green landscape. On closer inspection, you see why. These houses are not built *on* the hill; they're built *into* it. Just their glass facades and gleaming white

Continued





Agora, an earth-integrated housing project at St. Pierre de Feric, near Nice, France, is built on a 50 percent slope (top). A special building method called Reinforced Earth makes such construction practical. (See text for explanation.) When the houses are finished, earth will be mounded around and on top of them, so that the front yard of one becomes the roof of the one below. Architerra's prototype house, above, was built on flat land near Madrid, Spain. An earth berm was formed around and over the structure. The same soil-reinforcing technique was used. The painting, left, illustrates all the steps in building an Architerra development, from the initial sculpting of the land to the finished houses. The houses can be of any size and configuration and can have either one or two stories. Some have back patios and entries, as well as front. The company, which has an office in the U.S., also promotes the Reinforced Earth construction method for commercial buildings.

Huge new sports center:

How the Garden grew



Text and Drawings
By HENRY COMSTOCK

New York's Madison Square Garden is a "layer cake" of action and exhibitions

ROUNDHOUSES used to hide behind railroad depots. Now one sits, like a caramel-and-nut-frosted cake, on the site of New York City's razed Pennsylvania Station. It's a seven-layered setting for sports gourmets—the new Madison Square Garden.

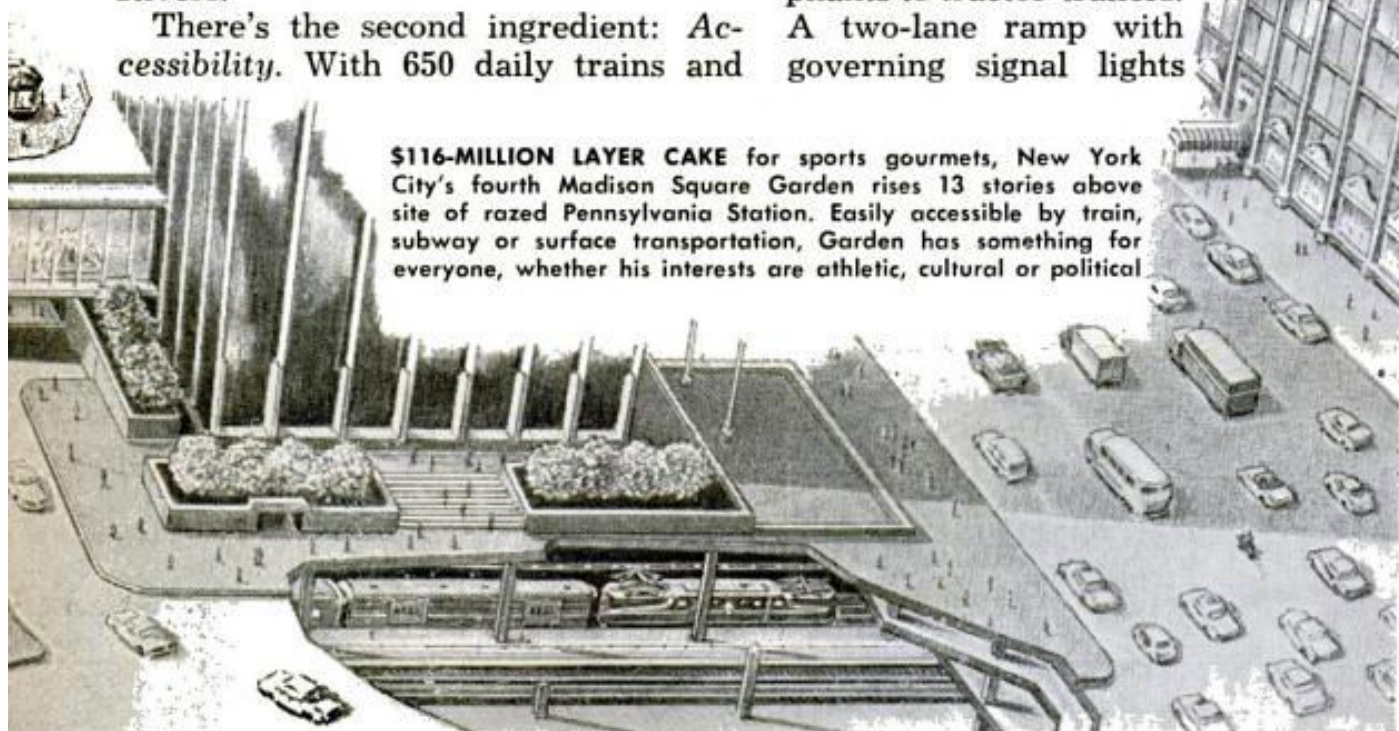
Money is the No. 1 ingredient. The circular "Center," along with a connected office building and five acres of greenery, has set the Madison Square Garden Corp. back \$116 million. That's only \$25 million less than the railroad paid, in 1910, for its splendid terminal, 13 miles of approaching real estate, and all of the hard-rock drilling under Manhattan Island and the Hudson and East Rivers.

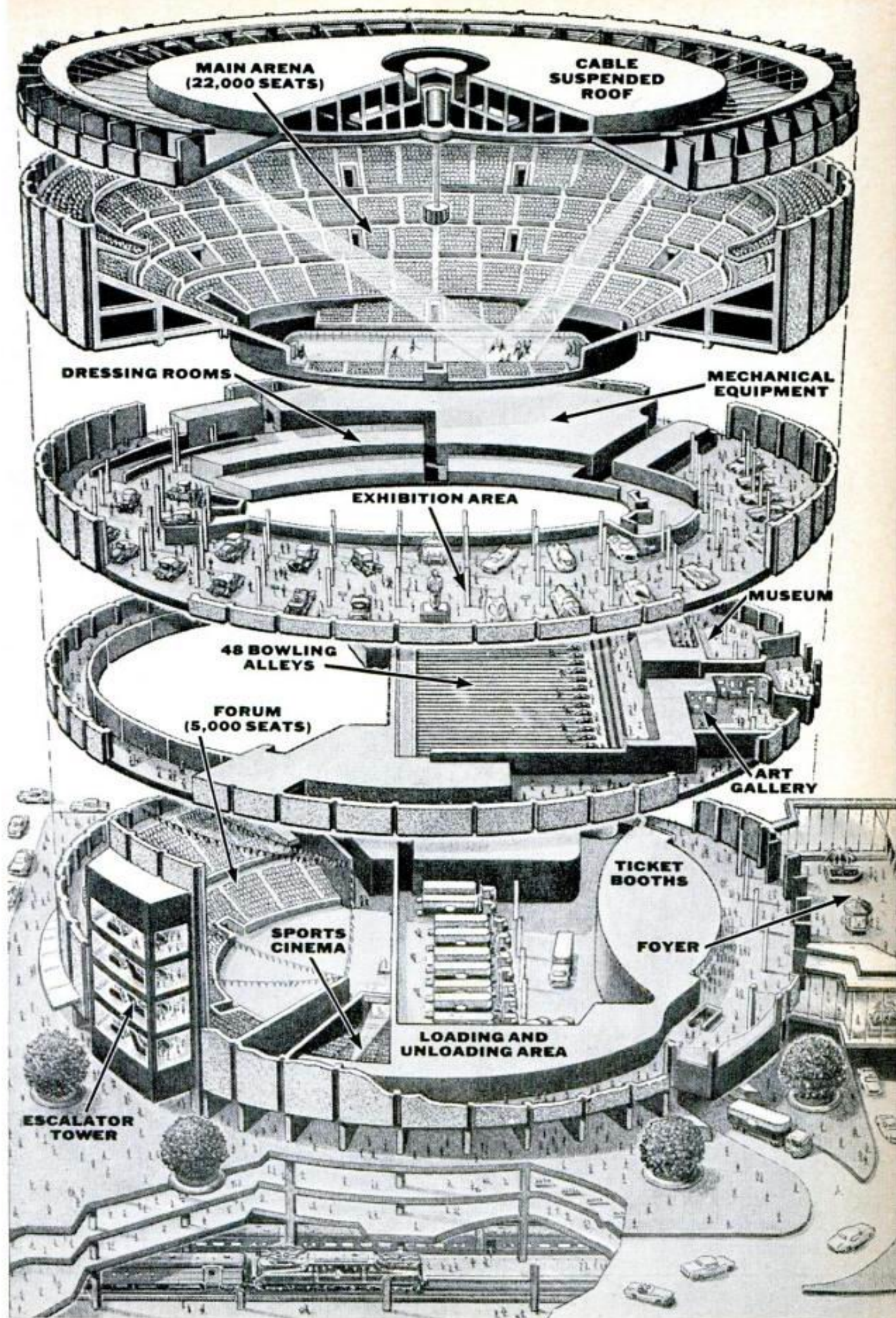
There's the second ingredient: *Accessibility*. With 650 daily trains and

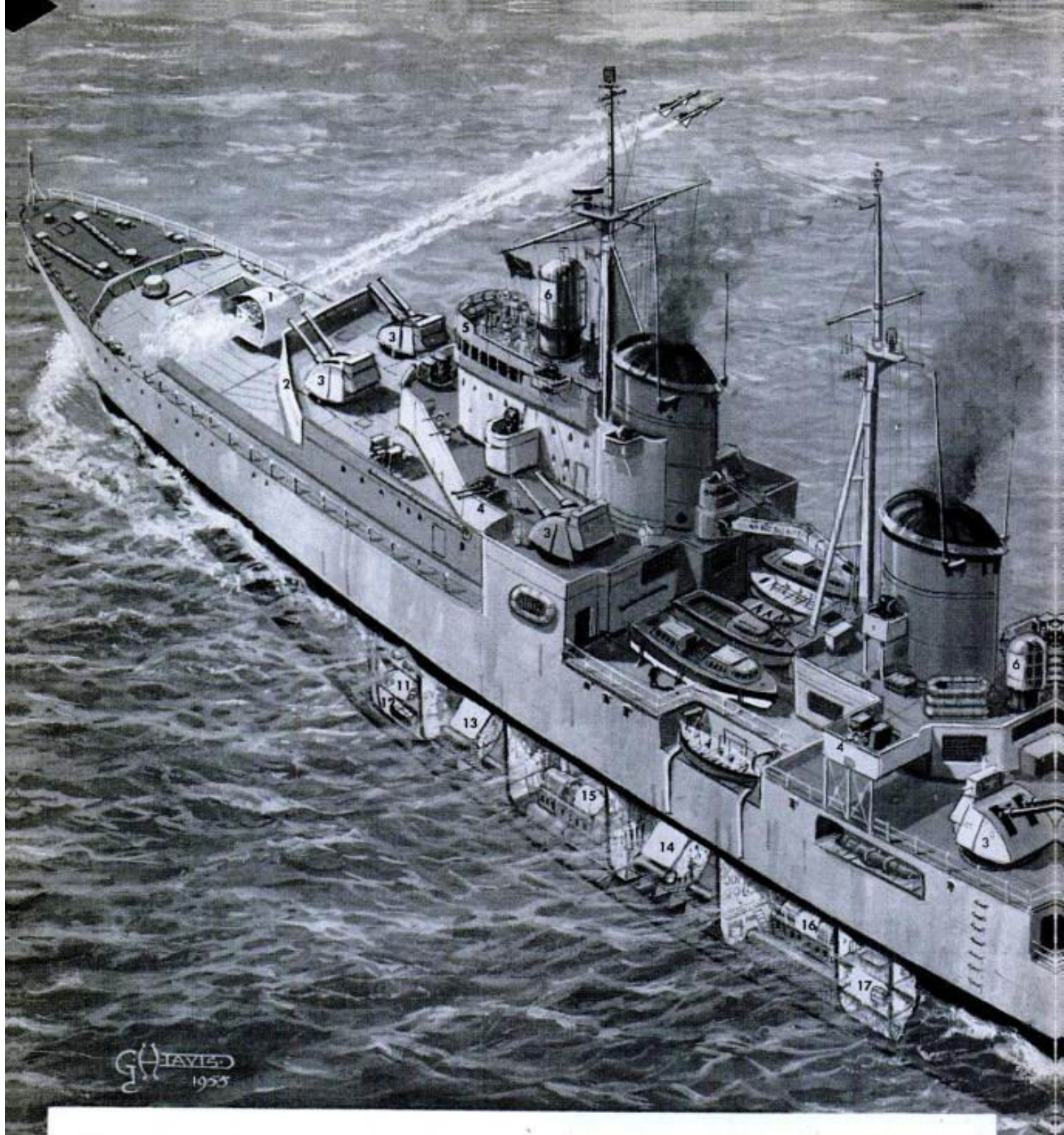
three interconnected subways underfoot, the Center is as easy to reach as a can of beer in the refrigerator. Leg-lazy sports fans don't even have to trudge up ramps to the amphitheater; a collective mile of escalators can fill or empty the entire building in 22 minutes.

You ride the most spectacular electric stairs in four glass towers flanking the 150-foot-high structure. Looking down, you see patrons who prefer a Versailles Garden approach pulling up to recessed curbs which accommodate 2000 automobiles an hour. Equally easy access is offered oversize visitors ranging from elephants to tractor-trailers. A two-lane ramp with governing signal lights

\$116-MILLION LAYER CAKE for sports gourmets, New York City's fourth Madison Square Garden rises 13 stories above site of razed Pennsylvania Station. Easily accessible by train, subway or surface transportation, Garden has something for everyone, whether his interests are athletic, cultural or political







G. H. Davis, noted London illustrator, gives readers of *Popular Mechanics* a preview on these pages of a design for a guided-missile cruiser for the British Navy. "Behind the scenes in the British Admiralty," Davis writes, "the department of the director of naval construction is formulating plans for the new guided-missile ships. Recently, suggested plans for one of these ships were released from the veil of secrecy and from them this drawing was made. I do not suggest that the drawing exactly follows the lines of these future ships, but it has been stated by experts that it is substantially correct." Britain's missile cruisers will have a displacement of 10,000 to 12,000 tons and will be armed with guided-missile batteries both fore and aft with a new secret system of fire control. (The USS *Boston* described in the accompanying article by Captain Brinckloe has missile launchers only on the afterdeck. The Admiralty's secret system of fire control is probably similar to the electronic Missile Control on the *Boston* which is de-

scribed in the article.) Davis reports that the British cruisers will have a speed of 35 knots and that in addition to the guided-missile batteries will have powerful armament including a main battery of five-inch dual-purpose guns. These guns have radar control and tremendous fire power. Secondary armament includes antiaircraft guns "of a new and secret type" in multiple mountings, also the latest weapons for anti-submarine warfare. The cruisers will be equipped with elaborate radar installations, stabilizers and even atomic-atmosphere control rooms fitted with radiation-detection devices. The Admiralty has rebuilt a Landing Craft Maintenance Ship as an experimental guided-missile "cruiser" and is conducting extensive tests. (The U.S. Navy held similar tests over a period of many months on the battleship USS *Mississippi*.) Britain's proposed guided-missile cruiser is "the obvious successor to the cruisers of today," according to the First Lord of the Admiralty.



NACA has experimented with designs like this wing-tip ram-jet with horizontal control surfaces in the nose of ship



THE SHAPE OF TOMORROW'S PLANES

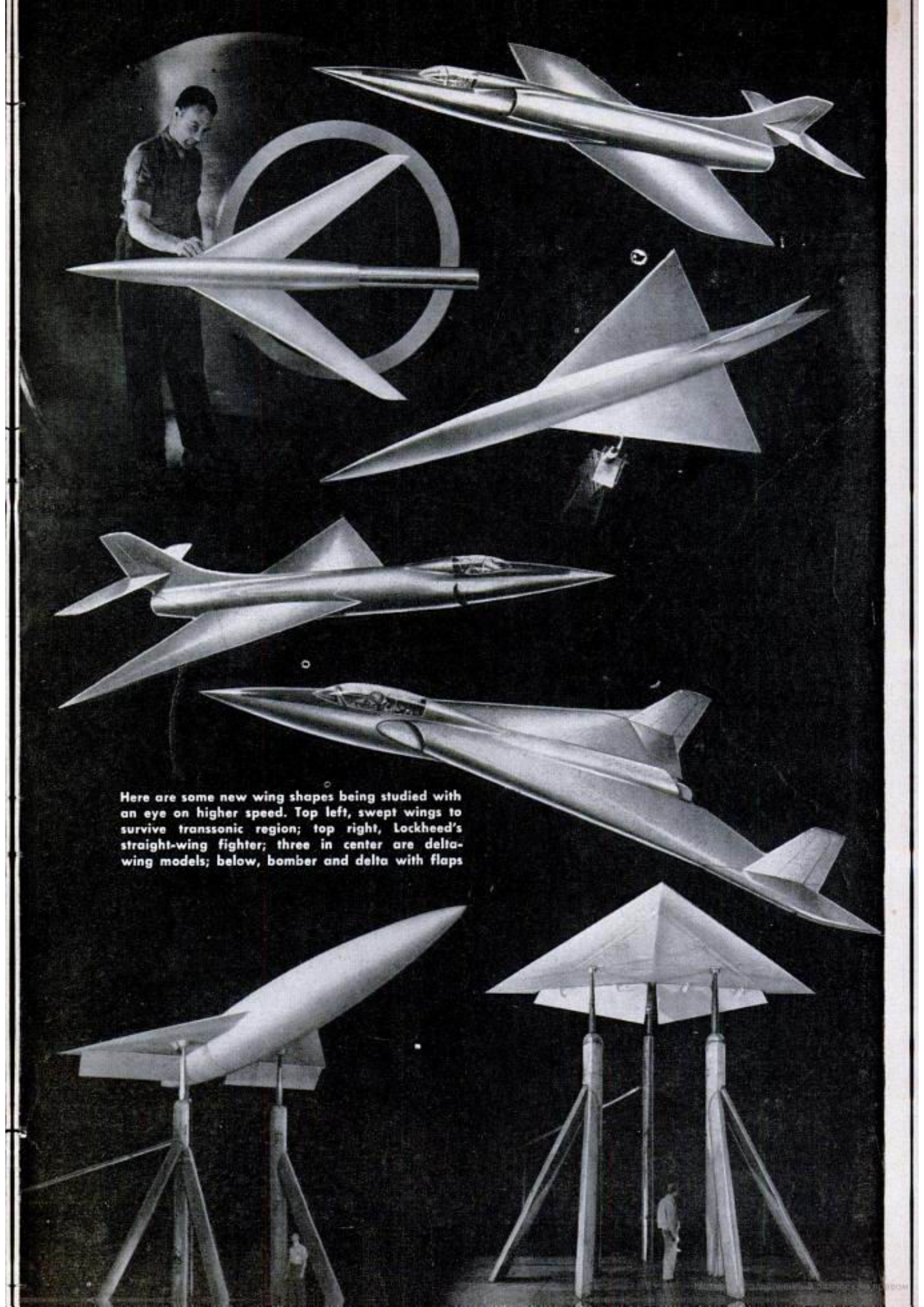
By Thomas E. Stimson, Jr.

BEHIND THE CLOSED DOORS of America's aircraft factories a battle of wits and wind tunnels is under way to decide the shape of tomorrow's high-speed airplanes.

"A thin, straight wing is okay," one engineer muses, "but where will we stow the fuel and landing gear? Can't pull a trailer behind the plane. We'll use a delta wing that has lots of room inside."

Grouped around the needle-nosed Douglas X-3 research aircraft, are types including straight wing, delta and swept-back wing model





Here are some new wing shapes being studied with an eye on higher speed. Top left, swept wings to survive transsonic region; top right, Lockheed's straight-wing fighter; three in center are delta-wing models; below, bomber and delta with flaps

"Trouble with the delta is its high landing speed," another decides. "We'd need to increase the size of the wing to get the landing speed down, and that increases the drag. A swept-back wing looks better."

And a third engineer, weighing the merits of all the shapes, concludes that a straight wing can't be beaten after all.

The result is that aircraft are taking on a variety of planforms never seen before. The Germans pioneered the swept-back wing design during the last war and made studies of the delta shape as well, but little else was done until about six years ago when North American tested its swept-wing F-86 and Boeing wheeled out its swept-wing B-47 bomber. At about the same time Consolidated Vultee was completing its XF-92A, a research plane with a triangular delta wing. This wing proved so successful that Convair has since flown two other high-speed delta aircraft, the F-102 and the XF2Y-1 Sea-Dart which is a water-based plane.

Official records don't yet suggest that any one shape is outstanding. In 1948, a swept-wing plane took the world speed record away from a straight-wing type, then last year one American and two British swept-wings each set new speed records in a row. Weeks later the Douglas F4D Skyray, a modified delta, captured the record at 753 miles per hour. Shortly afterward, a new North American swept-wing Super Sabre, our first supersonic combat plane, flew in excess of 754 miles per hour.

The competition hasn't ended and there's every chance that the delta F-102 will fly fastest of all when tested, possibly this year. And it might be that Lockheed's new straight-wing F-104 "air superiority" fighter will return the speed record to that type when it flies.

The 1327-miles-per-hour speed of the Skyrocket and the more than 1600-miles-per-hour speed of the Bell X1A, both rocket-powered research aircraft, are in a different category from the low-altitude records described here.

Much of the testing of these speedsters is performed at Edwards Air Force Base, Calif. This fabulous flight-test center boasts miles of rock-hard landing space including 65 square miles of Rogers Dry Lake. A new 15,000-foot runway is 300 feet wide with one end connected to the dry lake. This provides a seven-mile length of usable runway with a mile-wide "clearway" on either side with not even a fence post projecting from the surface. This is ideal for several research aircraft that have take-off and landing speeds in excess of 180 miles per hour.

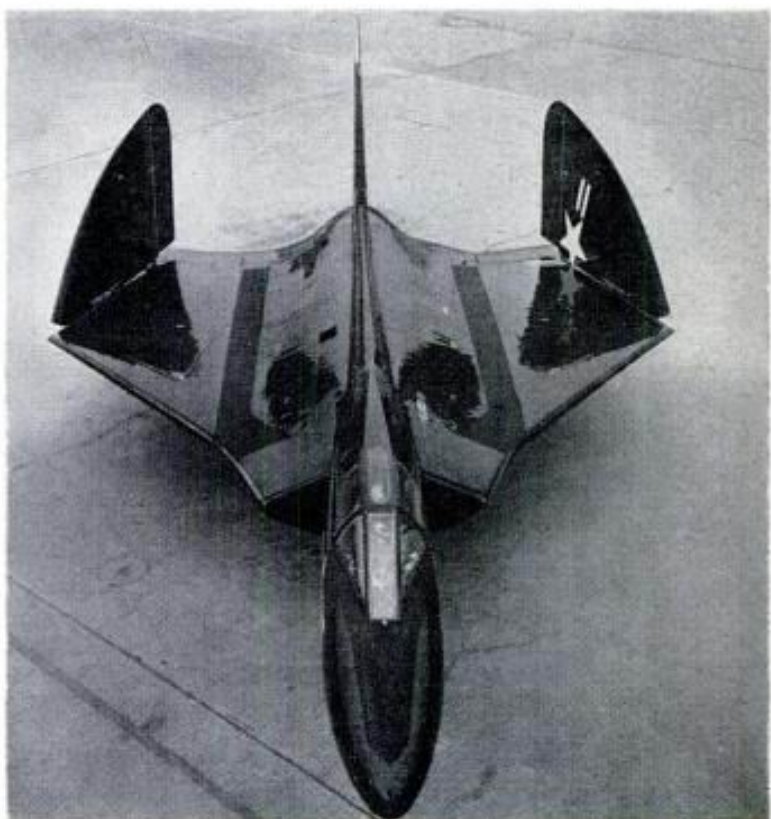
Plans are being made to extend the clearway on to Rosamond Dry Lake, seven miles

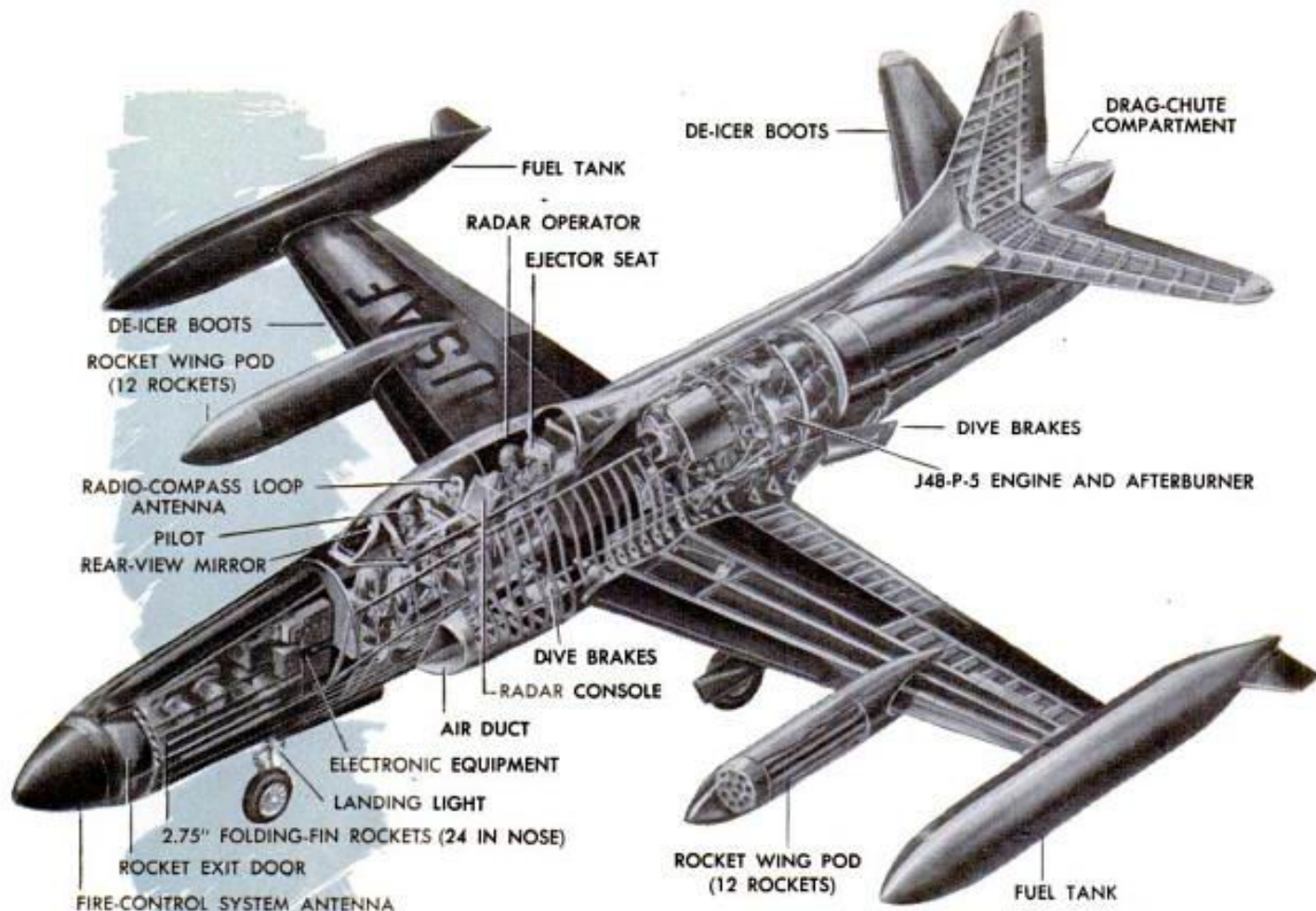


First U.S. delta-wing aircraft was a Convair XF-92A



Above, a Convair Sea-Dart, first delta wing water-based fighter, uses hydro skis. Below, Douglas XF4D-1 Skyray held short-lived record of 753 miles per hour





Cutaway above is of the Lockheed Starfire, a 600-miles-per-hour aircraft

from the end of the new runway. The combination of the two dry lake beds and the connecting clearway will provide 22 miles of straight-line landing area.

The control tower at Edwards is 140 feet tall. Men with field glasses and radio mikes can direct traffic on a runway that is a mile away. When the occasion demands, they can control take-offs and landings five or six miles away on Rogers Dry Lake.

In addition to flight testing both fast and heavy planes, Edwards is the home of the Air Force Experimental Test Pilots School.

Below, models of various straight, tapered, swept and delta-wing shapes tested recently at supersonic speeds in wind tunnels at research labs



LOCKHEED STARFIRE



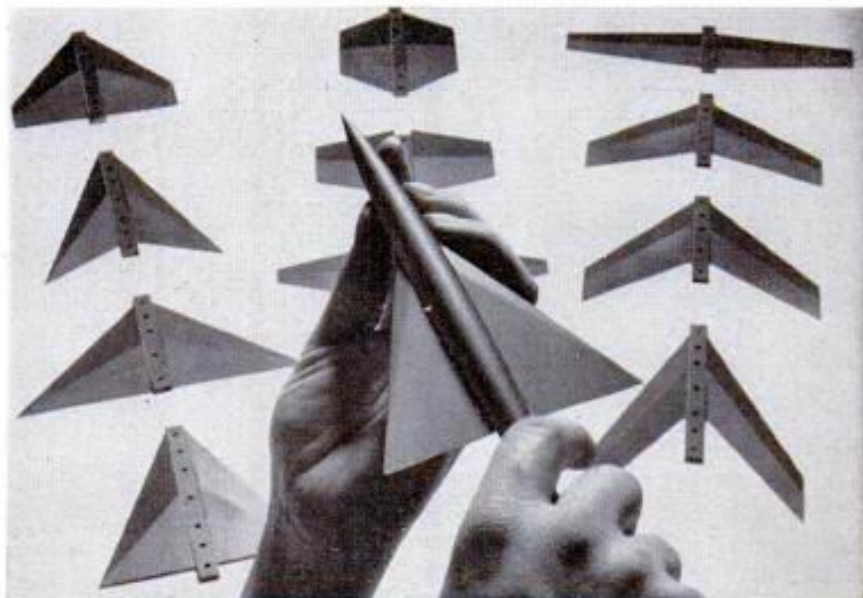
DOUGLAS SKYROCKET



DOUGLAS SKYRAY



CONVAIR SEA-DART

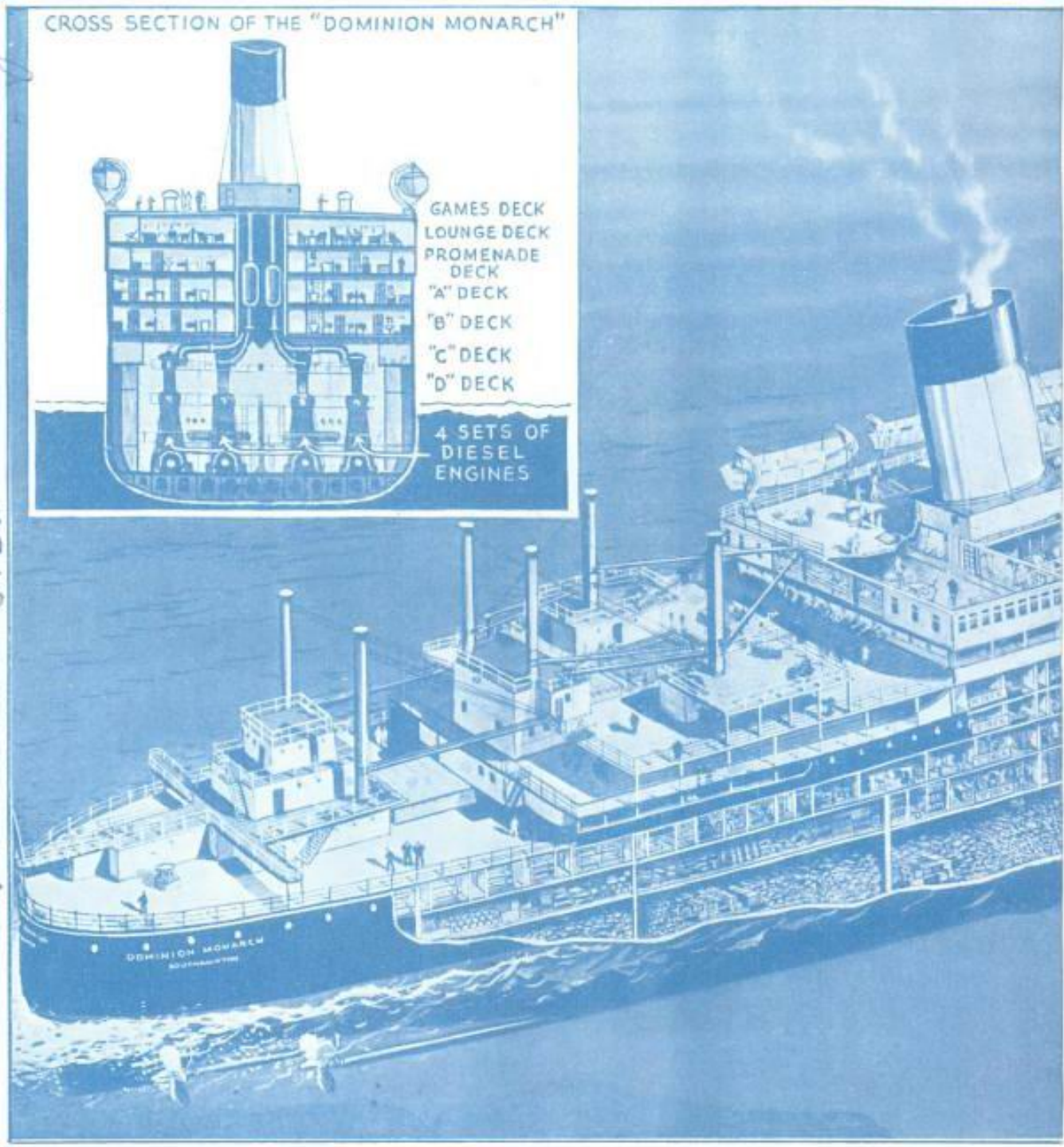
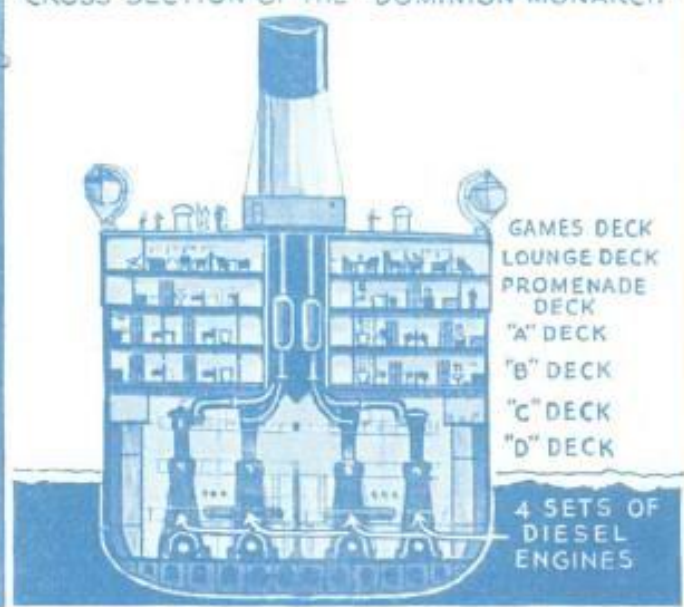


J 95

Shaw, Savill, and Albion Co
24, Leadenhall St. London E.C.3 England

GIANT DIESELS *Drive*

CROSS SECTION OF THE "DOMINION MONARCH"



POWERED by quadruple Diesel engines capable of developing 32,000 horsepower, England's latest queen of the seas, "Dominion Monarch," is regarded as the most powerful British motor ship afloat. The battery of engines, turning quadruple screws, gives the ship a service speed of twenty-one and one-half knots. Only first-class passengers will be carried on this

liner, which is rated at 27,000 tons, and accommodations are unusually extensive. The area of the sports deck alone is 18,500 square feet. Passenger cabins and public rooms embody the latest features in modern design. Cargo space, too, is large, as the diagrammatic drawing on these two pages shows. Refrigerating machinery, to supply cooling for cargo and passenger

Illustrated London News
Jan 11 1939

295

New OCEAN QUEEN

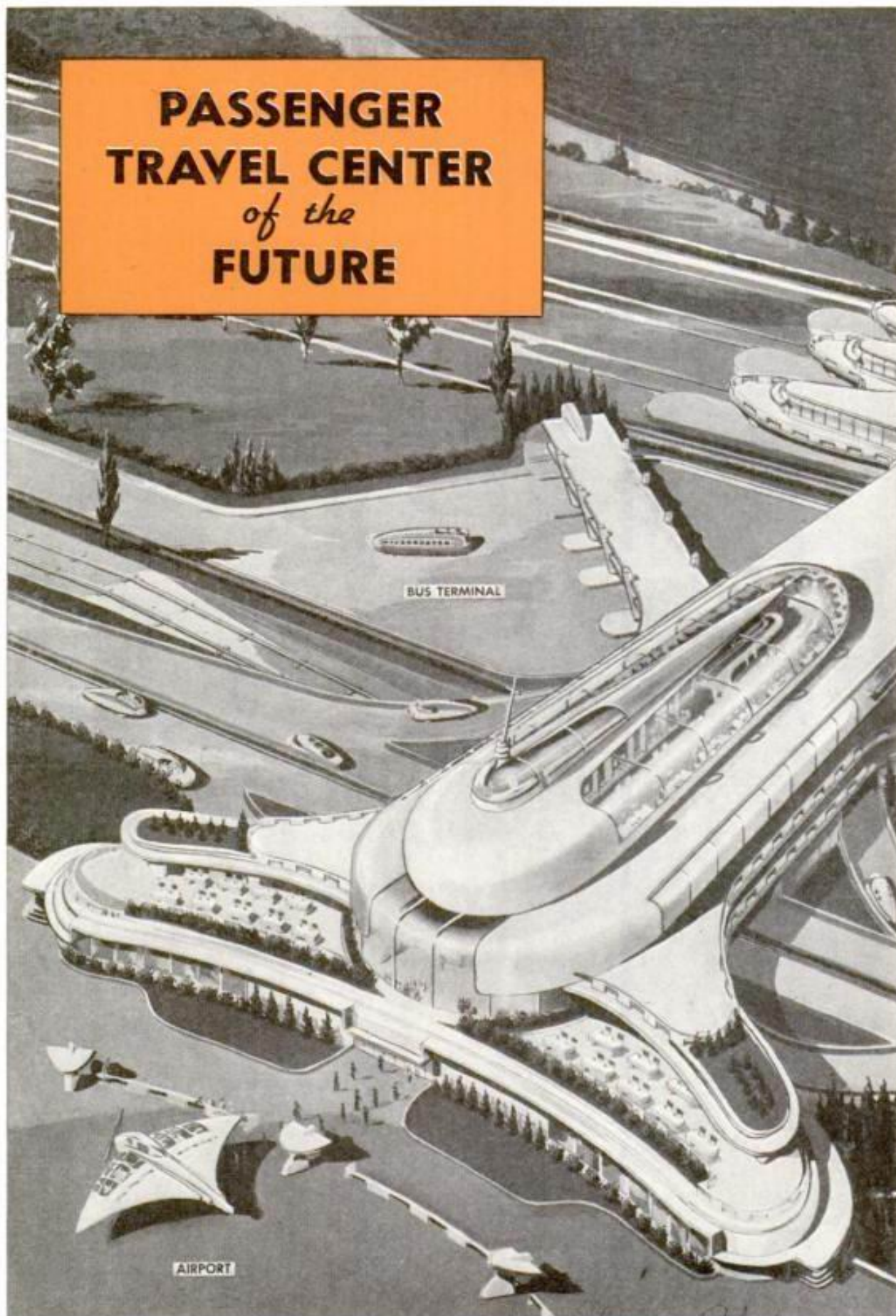


needs, requires four 160-horsepower motors. Two ninety-horsepower motors are used in connection with steering. An emergency lighting plant is driven by a 150-horsepower engine coupled to a 100-kilowatt generator. Equipment of the vessel includes a complete sewage installation, electrically operated watertight doors, fire-and-smoke protecting system, a special

fire-extinguishing system, echo sounder, radio and complete gyrocompass, as well as a sound-reproducing system with fifty-five loud speakers. The vessel, the largest engaged in regular passenger and cargo trades between England and New Zealand, via South Africa and Australia, is scheduled to reach Capetown in fourteen days, and New Zealand in thirty-five days.

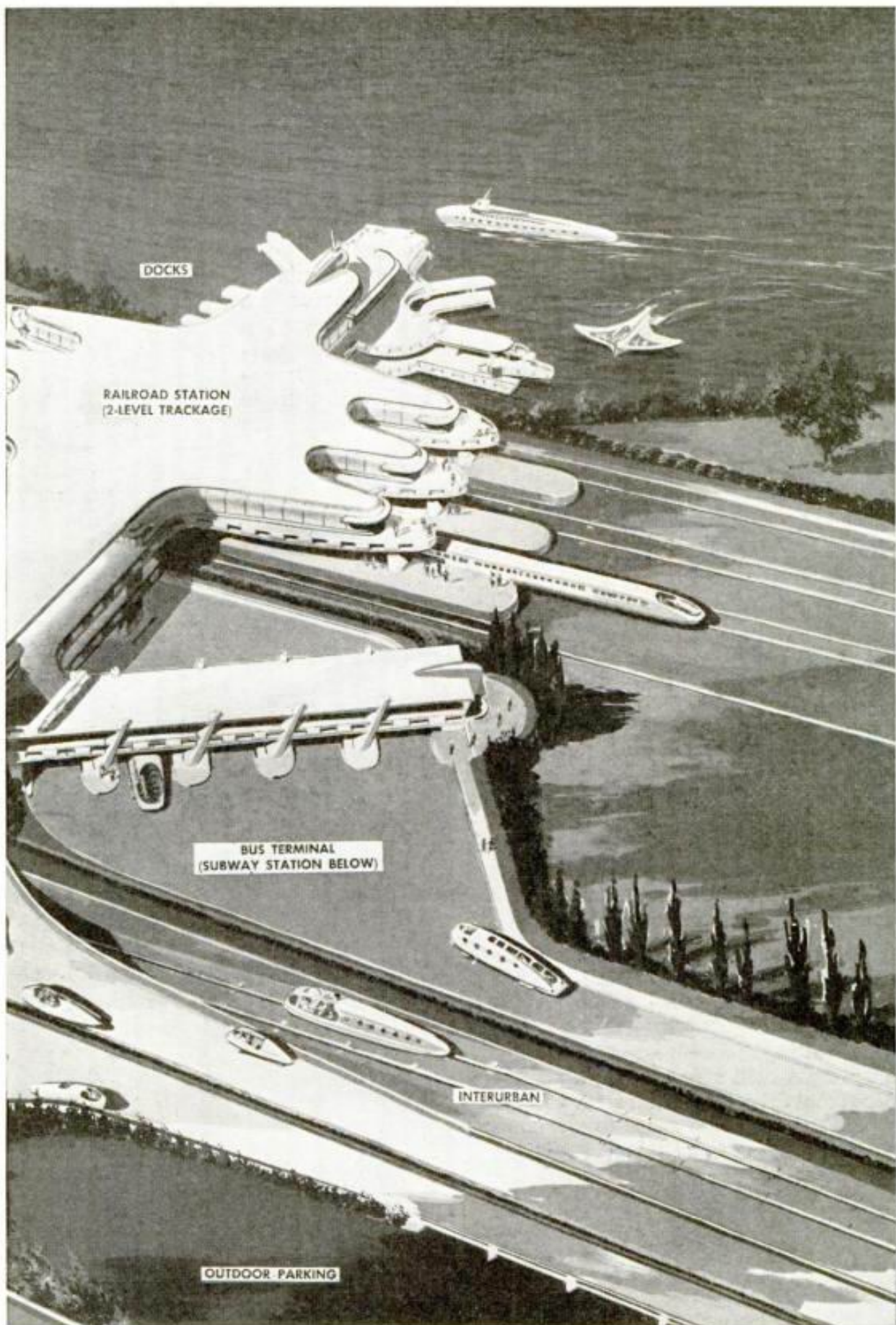
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PASSENGER TRAVEL CENTER *of the* FUTURE



Courtesy "Steel Horizons," published by Allegheny Ludlum Steel Corp.

What's ahead in transportation? Peter Muller-Munk, head of the School of Industrial Design at Carnegie Institute of Technology, suggests in this drawing that great travel centers will appear in the post-war reconstruction, served by railway, bus, plane, ship, subway, interurban and automobile



Instead of competing air, water, road and rail companies, there may be companies selling any form of travel. Such a travel center as this, a universal interchange point located on slum-cleared land or away from the "downtown" area, would relieve the city of much of its cross-traffic congestion



FRENCH ACX

BRITISH ACA

GERMAN TKF-90

Superfighters of the 1990s, shown here in artists' concepts, are (clockwise from the top): France's ACX, an advanced version of the famous Mirage; the British-German-Italian ACA; and MBB's TKF-90. All three combine fully movable canards with a delta-wing configuration that eliminates conventional tailplanes. Multipurpose control surfaces in the wing's trailing edge, such as elevons or flaperons, perform the functions of ailerons, elevators and flaps all in one—a modern trend.

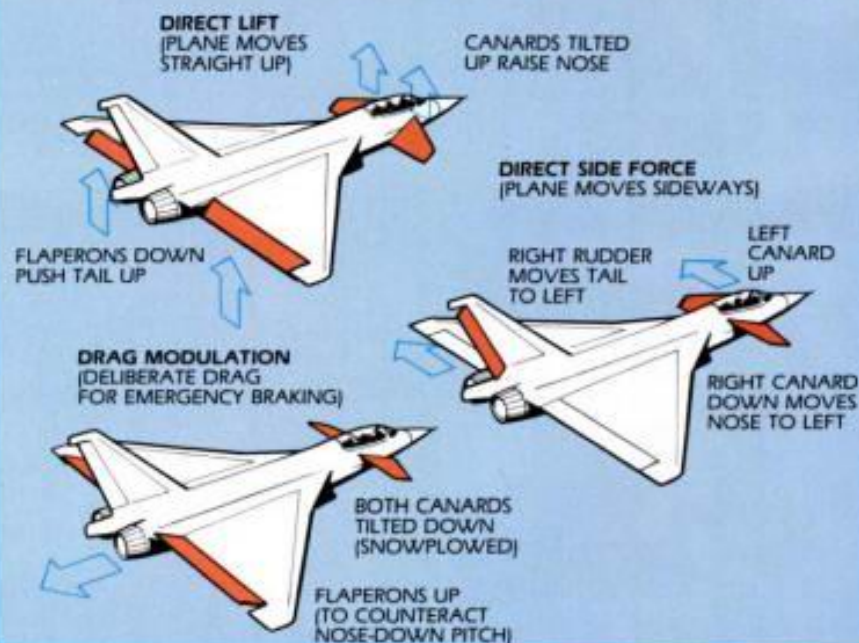
because the enemy may be temporarily lost from view during the turn.

In the AFTI/F-16, the pilot merely uses his canards plus opposite rudder to skid the plane into a flat, wings-level turn, a maneuver that takes much less time and keeps the enemy in full view. It also permits a much tighter turning radius—the hallmark of a superior interceptor. A fighter that can turn inside an opponent's path will usually emerge the victor.

The ability to point the nose up, down or sideways independent of flight path—called pitch pointing and yaw pointing—enables a pilot to keep his gunsight trained on an elusive quarry without taking the time to climb, dive or turn in the conventional manner. Moving the entire plane up, down or sideways—called vertical or lateral translation—allows a pilot to dodge away from a pursuing attacker or pull up sharply at the end of a bombing run to evade ground fire.

Such fancy aerial footwork is the result of several new technologies that represent a radical departure from traditional aircraft design. Since the beginnings of aviation, airplanes have been made to be inherently stable. Wing lift is located behind the center of gravity (CG) so that upward forces encountered in turbulence or during a maneuver tend to push the nose back

HOW CANARDS CAN MAKE A PLANE DO CRAZY THINGS



It's all in those funny ears on the nose: Drawings above show how all moving canards, functioning like the diving planes on submarines, permit heretofore impossible maneuvers. Tilting the canards up and flaperons down (top) exerts lift on the nose and tail simultaneously, moving entire plane straight up without the craft entering a slow climb—useful, for instance, for gaining altitude fast at end of

a bombing run. Using the canards differentially—one tilted up and the other down—forces the nose sideways (center). At the same time, applying reverse rudder pushes the tail in the same direction. Together, they allow the plane to slide sideways without turning. With both canards tilted down like a snowplow (bottom), sudden drag slows plane abruptly to fool a pursuer.

GRUMMAN'S 'WRONG-WAY WING': RIGHT FOR THE FUTURE?

Grumman's futuristic forward-swept-wing X-29A, shown here as model, is due to fly next year. Drawings show how airstream flows outward on conventional aft-swept wing, but inward on forward-swept design, leaving wingtips in clear air. Advantages: higher lift, lower drag, lack of wingtip stall and improved maneuverability.

CONVENTIONAL AFT-SWEPT WINGS



AIRFLOW MOVES OUTWARD,
HASTENING WINGTIP STALL

NEW FORWARD- SWEPT WINGS



AIRFLOW
MOVES
INWARD,
DELAYING
WINGTIP
STALL

down. The plane, after a disturbance, returns automatically to straight and level flight, even if you take your hands off the controls.

This makes for an airplane that's safe, docile and easy to fly, but also one that tends to resist sudden changes in attitude. A further disadvantage is that a download is constantly imposed on the tail to counterbalance the weight of the nose and keep it from pitching downward. The tail thus generates drag, but no useful lift.

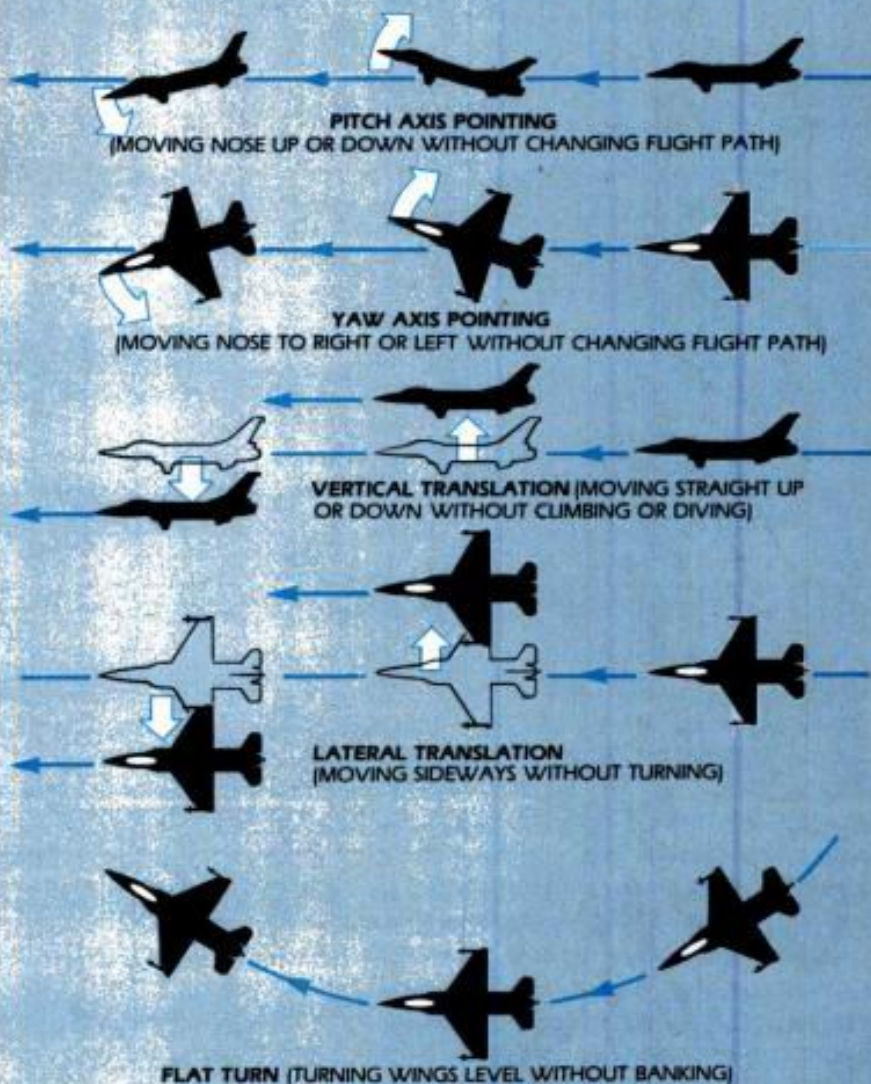
If you give up natural stability, surprising things happen—some good, some bad. By moving wing lift ahead of the CG, the nose is constantly forced upward so that downloading on the tail is no longer needed to keep the plane in trim. The tail now becomes a lifting surface, helping the wings to support the plane. The wings can then be made smaller and lighter, saving weight, reducing drag and improving overall responsiveness.

In addition, a plane with no tendency to remain in stable flight is suddenly free to execute maneuvers much more quickly and violently than a conventional aircraft.

Sounds simple. Why not make all airplanes this way? The problem is that an unstable aircraft is virtually unflyable—so skittish that no human pilot

(Please turn to page 125)

NEW DECOUPLED MODES OF FLIGHT



In conventional aircraft, control surfaces are operated together to produce coordinated maneuvers. In future fighters, controls will be

"decoupled"—operated independently of each other—permitting strange new maneuvers (above) with equally strange names.

SPACE STATION:

'The Next Bold Step'

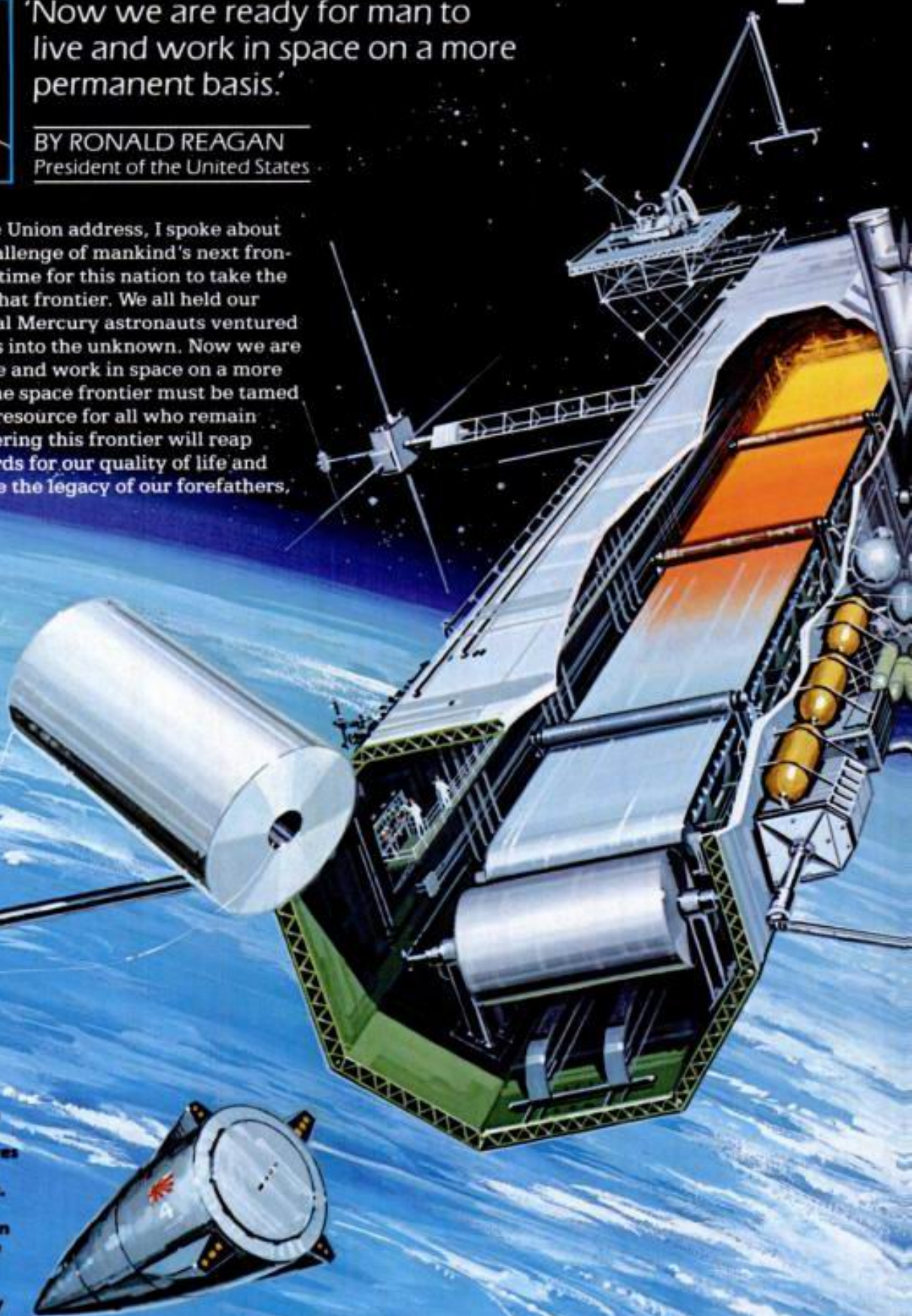


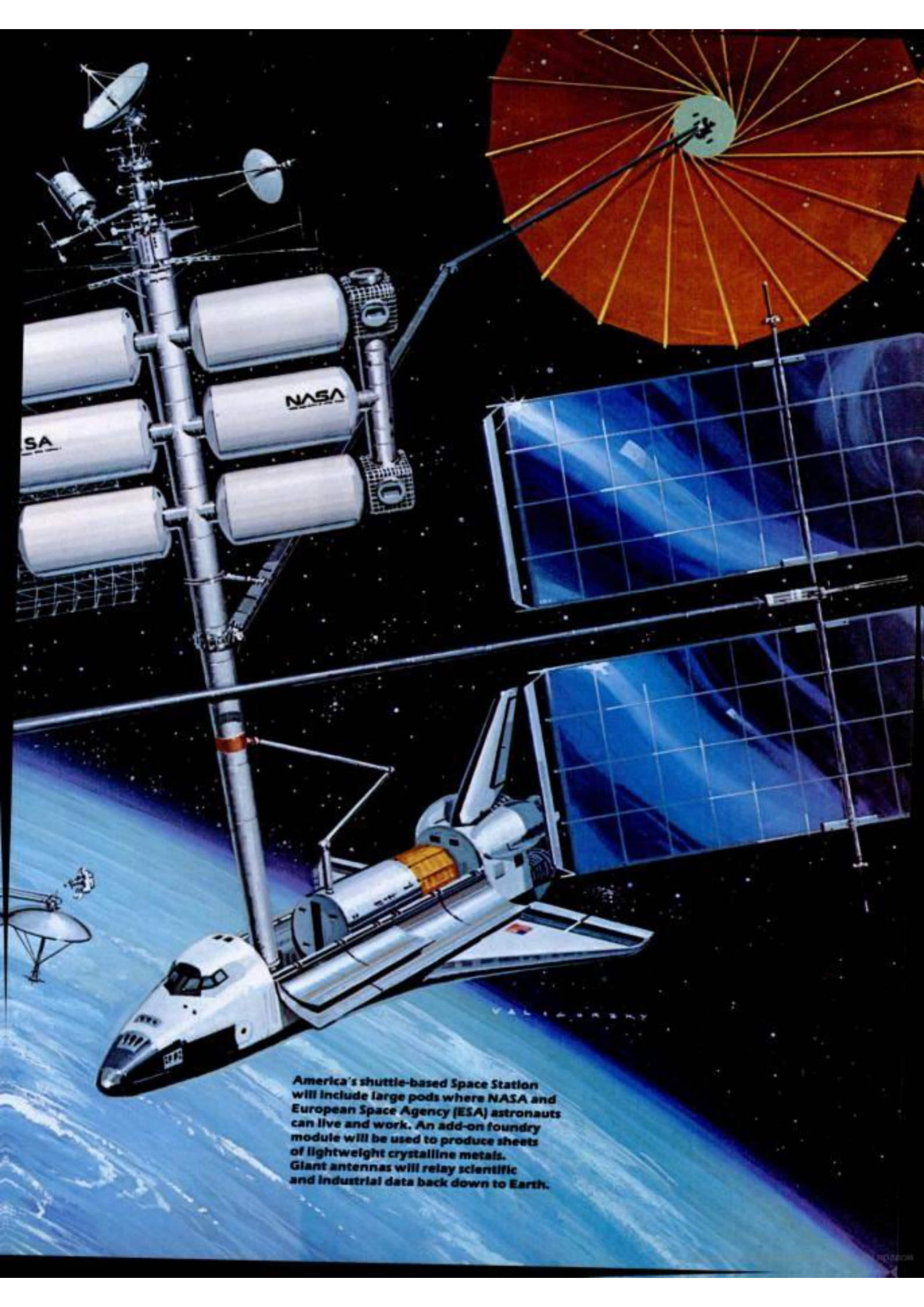
'Now we are ready for man to live and work in space on a more permanent basis.'

BY RONALD REAGAN
President of the United States

In my State of the Union address, I spoke about taking on the challenge of mankind's next frontier—space. It is time for this nation to take the next bold step into that frontier. We all held our breath as the original Mercury astronauts ventured on their short flights into the unknown. Now we are ready for man to live and work in space on a more permanent basis. The space frontier must be tamed and developed as a resource for all who remain earthbound. Conquering this frontier will reap unimaginable rewards for our quality of life and will help us preserve the legacy of our forefathers.

A roll of crystalline metal floats outside foundry module as an astronaut in a jet-powered chair prepares to load it onto a Japanese ferry rocket. Production of lightweight metals that can be made only in space will be a mainstay of our Space Station. Japan has successfully tested ferry rockets.





America's shuttle-based Space Station will include large pods where NASA and European Space Agency (ESA) astronauts can live and work. An add-on foundry module will be used to produce sheets of lightweight crystalline metals. Giant antennas will relay scientific and industrial data back down to Earth.

TECHNOLOGY UPDATE

AVIATION



New tilt-engine jet flies like a helicopter

When you want to go up, you just tilt your engines upward in this dramatic new V/STOL concept under joint development by Grumman, NASA and the U.S. Navy. With the engines horizontal, it flies like a conventional airplane; with the engines vertical, it lands and takes off like a helicopter.

A full-scale mockup of the craft (inset at right) is already undergoing wind-tunnel tests.

Unlike other tilt-rotor designs requiring elaborate control mechanisms, the Grumman engines are mounted on a simple hinged spar that swings up like a trap

door, rotating the jets to any desired angle from horizontal to vertical.

Called the Design 698, the twin-turbofan craft will have a speed of 575 mph, a range of more than 1,600 miles and the ability to climb like an express elevator at 12,000 feet per minute.



In addition to its role as a military jump jet, the new plane is also expected to have important peacetime applications as a short-field business aircraft and a cargo plane for supplying offshore oil rigs.

Coming: Smaller jetliners

Airliners are getting smaller and smaller in an effort to reduce operating costs through the use of lighter, more fuel-efficient jet engines and the economic advantage of flying with full passenger loads instead of half-empty cabins. The latest to undergo the shrinkage treatment is the European-built Airbus A320, a downsized version of the A310 designed to seat only 150 passengers. (The A310 and the recently introduced Boeing 767 are both in the 200-plus-seat class.)

The twin-jet A320, shown in the artist's conception below, will have a range of more than 2,000 miles and is expected to burn 44 percent less fuel per passenger seat than today's jetliners. Due to

start production soon, it's scheduled to go into airline service in 1988. Boeing's answer is not yet known, but is rumored to be either a 150-seat version of its 737 or an all-new 150-seater cryptically designated the 7-7 (the dash stands for the as yet unspecified middle numeral).

Meanwhile, the British-built BAe 146 (lower left) is also making news as the world's quietest jetliner. Powered by four low-noise, high-thrust turbofan engines, the short-haul 100-seater can operate from small intercity airfields and is said to burn less fuel than twin-jet airliners, while being nearly twice as quiet as any jet. According to its maker, British Aerospace, it will, for the first time, bring the speed and luxury of jet travel to

short-run feeder routes now served only by slower, more spartan turboprops. Here in the United States, Air Wisconsin has already adopted the BAe 146 for its feeder-line operations.

For today's financially hard-pressed airline companies, the skies may be looking more friendly than ever. For U.S. aircraft manufacturers, however, some dark clouds are blowing in from abroad.

Editor: Dennis Eskow
Contributors: Sheldon M. Gallagher, Jack Hammond, Bill Johnston, Jack M. Kneese Jr., Michael Bargo Jr., John Dornberg, Leif Robinson, Lee Green, Fran Wenograd, Golden

Two new downsized jetliners: Airbus A320 (right), BAe 146 (below).





GI of the future? Army's six-legged robot can carry nearly 900 pounds of armament or other gear at a brisk walk.



ROBOTICS

Remote-control GIs

Sending mechanical soldiers out to do your fighting for you may sound like comic-strip humor, but it's no joke to the U.S. Army. A six-legged, TV-eyed, remotely controlled robot, said to be the first to have true walking mobility, is currently undergoing tests to see if it can perform combat missions too hazardous for humans.

The spider-like creature, its articulated legs powered by 18 electric motors, can climb, stoop, squat, crawl and otherwise simulate most human contortions. An on-board computer

constantly monitors its center of gravity to keep it from losing its balance as it gleefully scampers over obstacles as high as 33 inches.

Called Odex I, the robot will initially be programmed to prowls suspected minefields, lay smoke screens, make reconnaissance patrols and do other relatively simple battlefield chores. Later, the Army hopes to be able to "train" the robot so that it can stalk enemy tanks, fire rockets, hurl hand grenades and serve as fearless medics to evacuate casualties under fire.

Made by Odetics Inc. of Anaheim, Calif., the Odex I is also expected to have important civilian applications in such dangerous jobs as firefighting, law enforcement, deep-level mining and nuclear waste disposal.



Two prototypes (left) and artist's conception (right) of prison robot.

Robot from cellblock H

His name is Denny. He's a prison guard. He stands just 4 ft. tall and weighs 400 pounds, but he moves fast. Denny is a robot designed by Denning Mobile Robotics of Woburn, Mass. By next year, the metal-clad droid will cruise prison halls in Massachusetts and other states at 3 mph. Microwave, infrared and chemical sensors will pick up heat, motion and even body odor of unauthorized personnel. By 1986, nearly 1,000 Dennys are expected to go on duty around the world.

INVENTIONS

Britannia rules the waves

We're talking about magnetic waves. Britain's Maglev car starts riding the rails this fall between the Birmingham airport and the National Exhibition Center. The system has the first magnetic switching tracks. It works by swiveling into position, pushing aside the rail from which the car is changing. The car carries nine passengers.



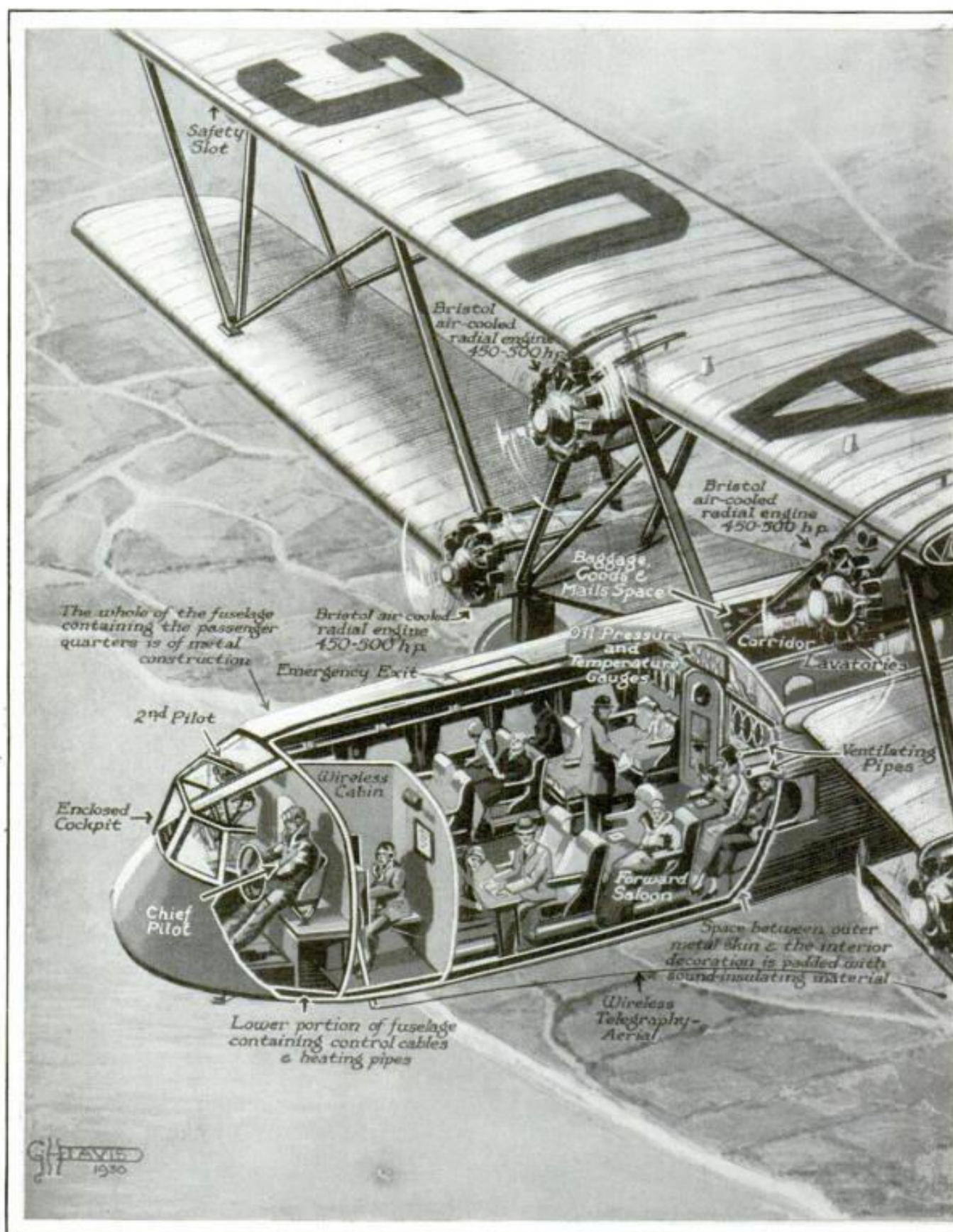
A Maglev switch track swings into place in Britain's system.



'Creep' show comes to an end

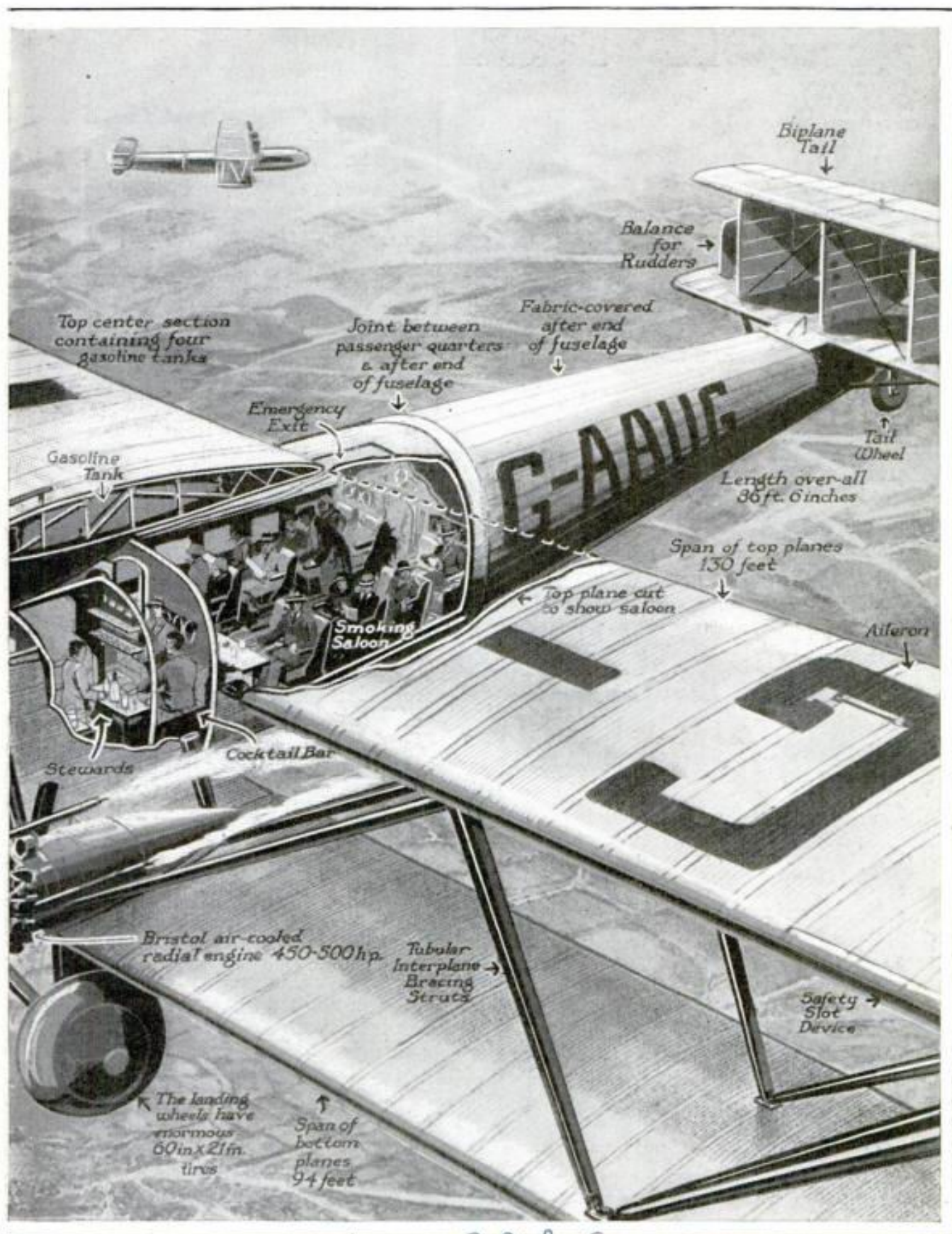
A locomotive speedometer often reads far higher than the car is actually traveling. That's due to "creep" on low-friction track. The wheels turn fast, but the car loses speed. GM Electromotive has introduced a locomotive that fires radar on the track. As the beam bounces back, true ground speed is measured and throttle can be adjusted to save fuel.

THE WORLD'S LARGEST AIRPLANE PROVIDES ALL



Courtesy The
 Artist's Sketch of Big Plane for Imperial Airways; a Fleet of These Large Air Liners Is Being Built and One Already Has Been Given a Test Flight

MODERN LUXURIES FOR FORTY PASSENGERS



Illustrated London News

11/22/30 P. 928-9

These Planes Will Have an Estimated Cruising Speed of 100 Miles an Hour with Four Radial Air-Cooled Engines, Each of 450 to 500 Horsepower

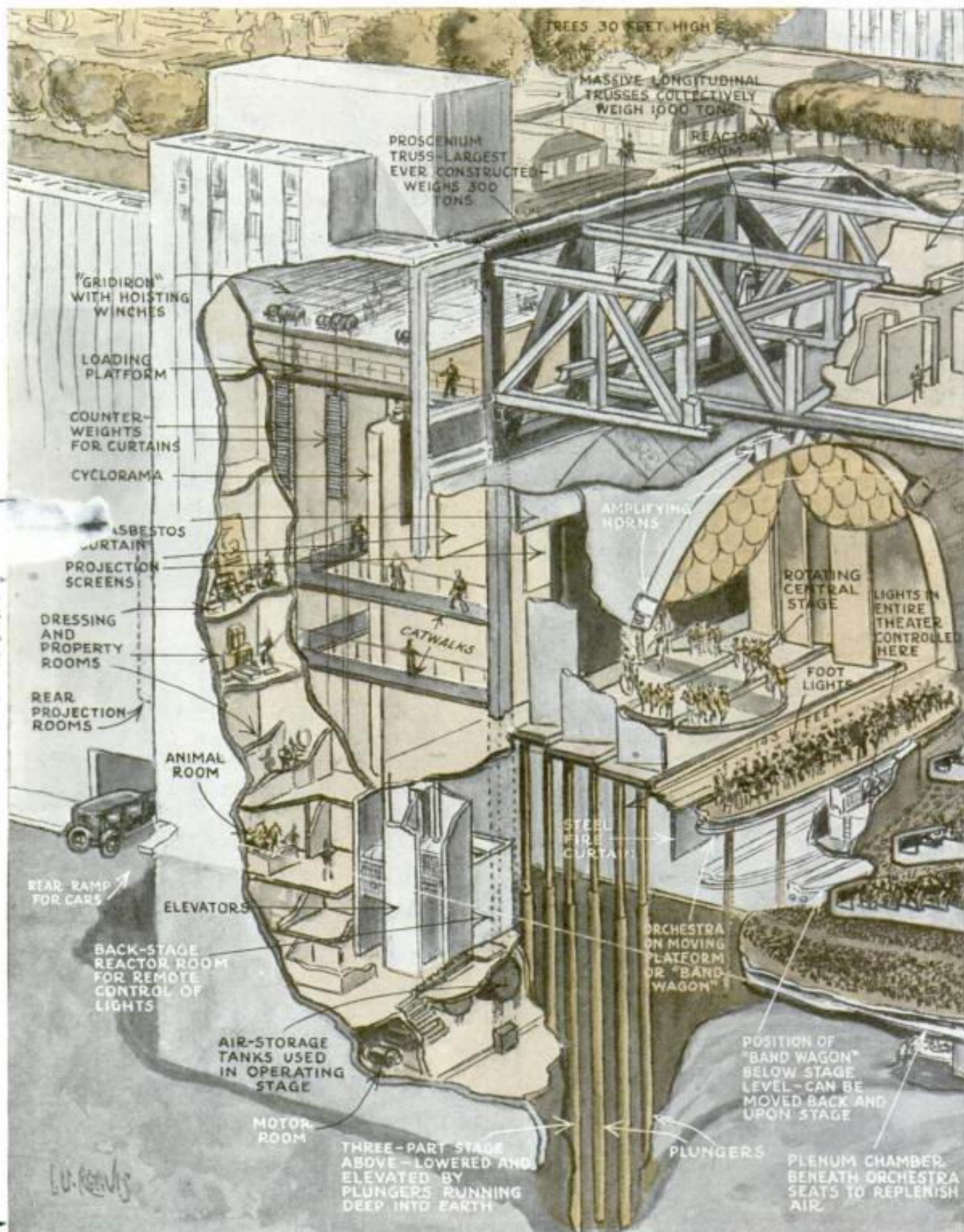
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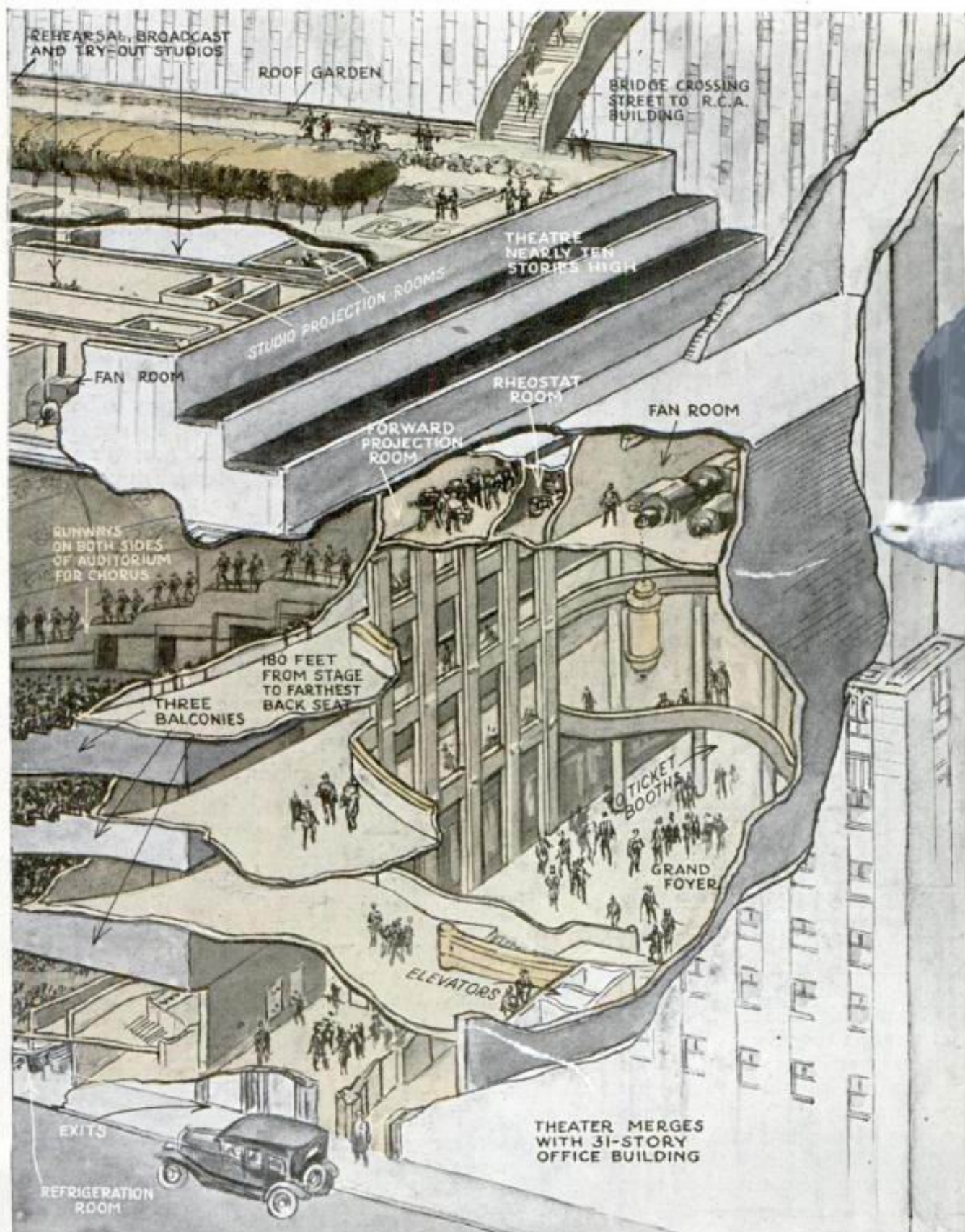
POPULAR MECHANICS

World's Largest Theater in Rockefeller



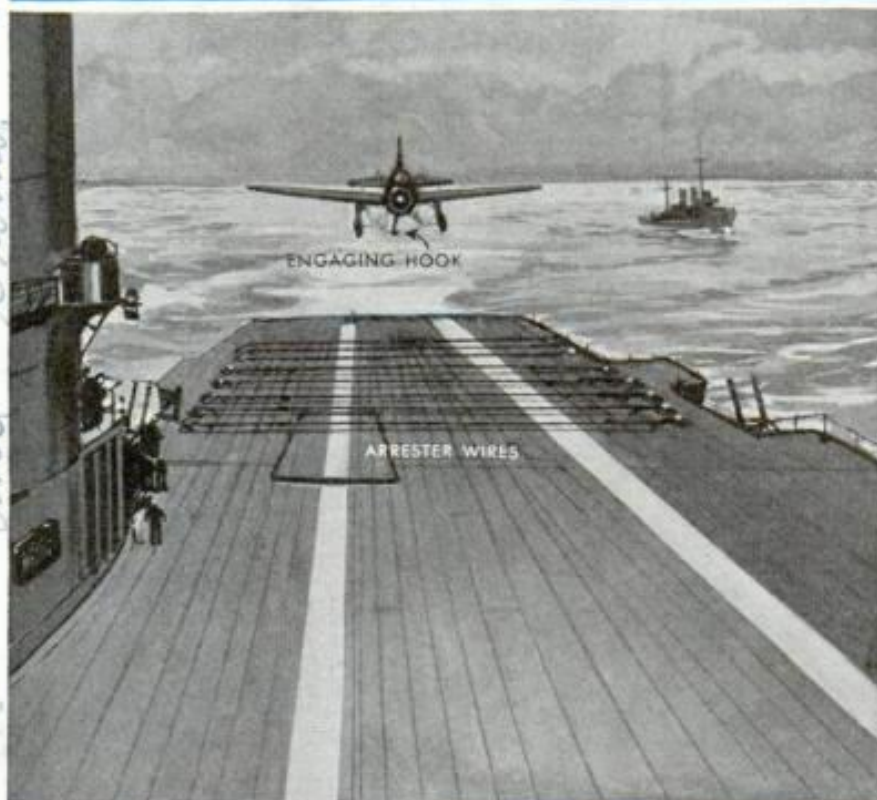
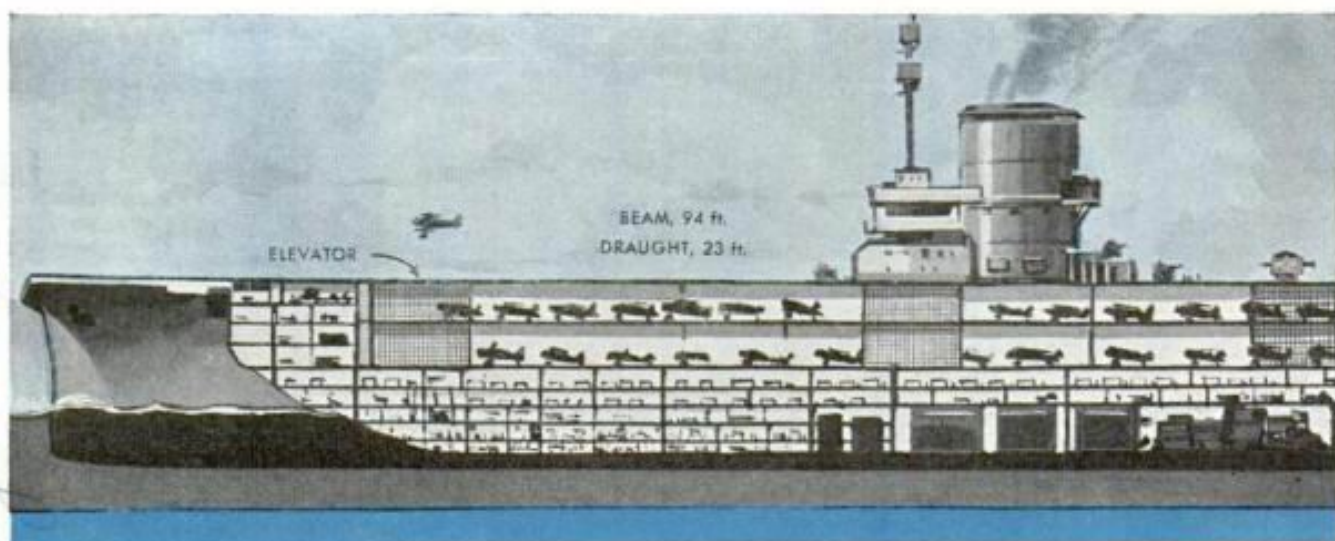
Sectional Drawing of International Music Hall under Construction at Rockefeller Center in New York; It is Nearly Ten Stories High and Will Seat Over 6,100 P.

Center Will Seat Six Thousand Persons



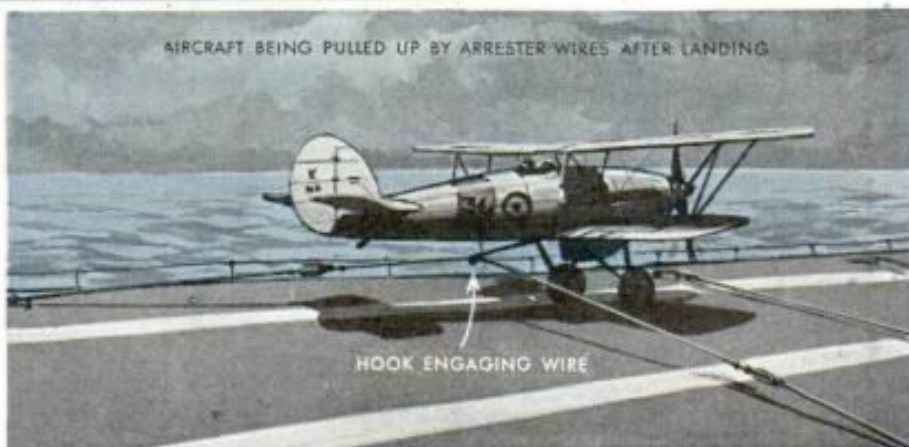
Note Revolving Central Stage and "Band Wagon" on Which Orchestra Can Be Moved from Position in Front to Place on Stage; the Stages⁵⁰⁰ Triplicate, Can Be Elevated Thirty-Two Feet

Wires Halt Aircraft Landing on Ship's Deck

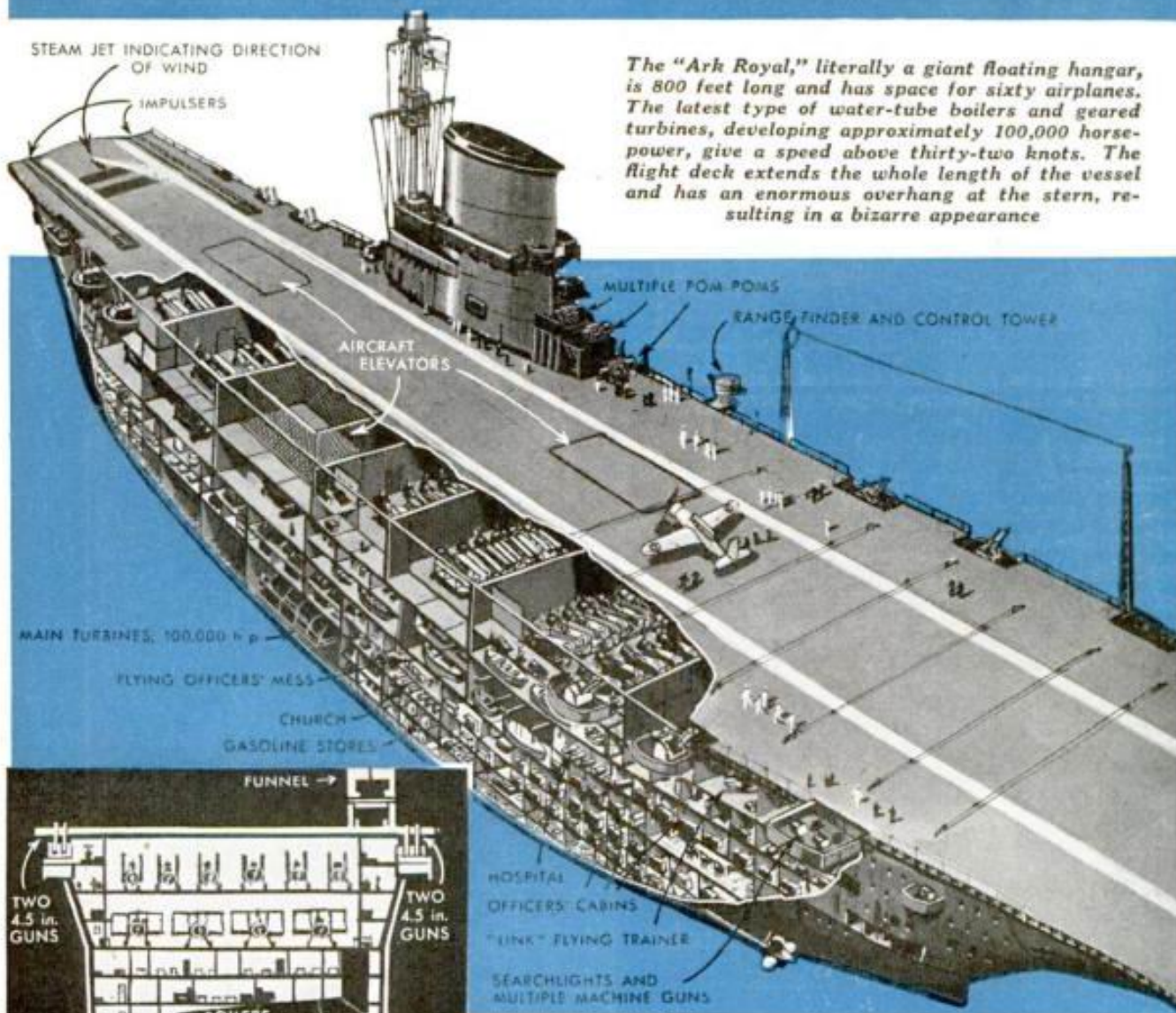
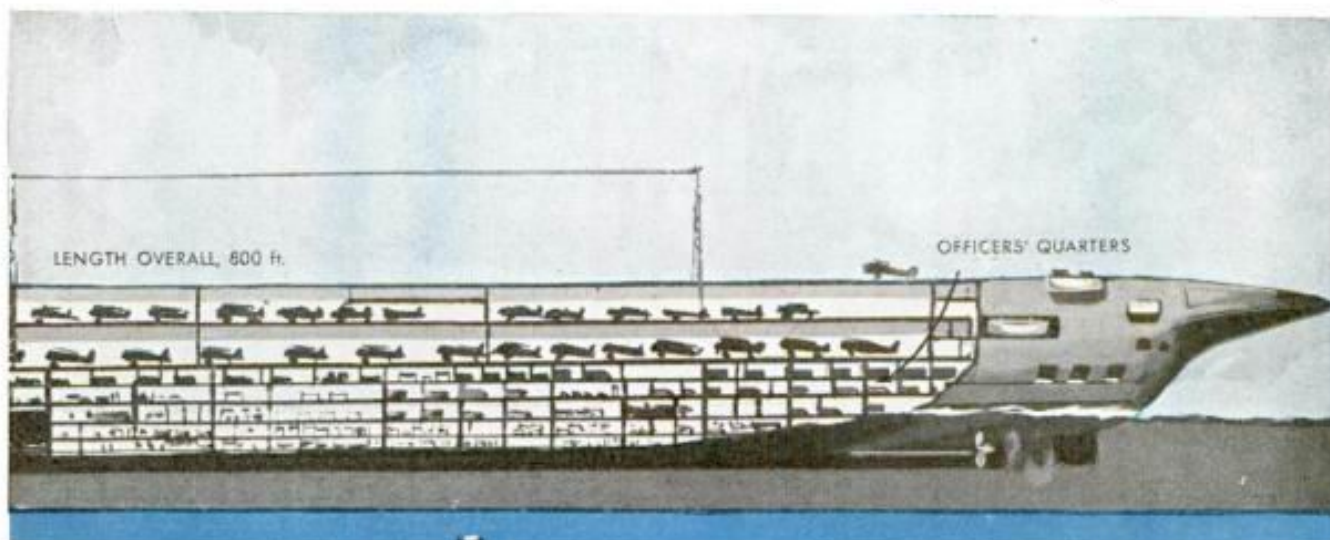


Among the many features of Great Britain's latest aircraft carrier, H.M.S. "Ark Royal," pictured at top in cross-section view, is a secret mechanism for halting planes as they land on the deck. This consists of wires stretched across the deck, as shown at left, sufficiently high to be engaged by a hook lowered by the pilot of an incoming plane. Forward of the vessel's hangars are two runways for a modified form of catapult, known in the service as "accelerators." Three elevators are provided for raising aircraft from the hangars to the flight deck. Drawings presented here were prepared with the aid of the British Admiralty

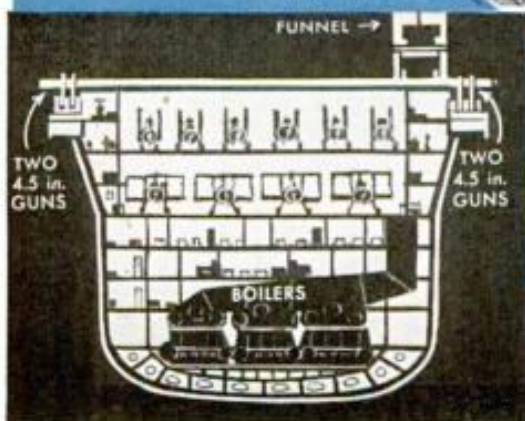
After the hook of the incoming plane has engaged one of the wires stretched across the carrier's deck, as shown at right, a new type of arrester mechanism brings the plane to a stop without a jerk, applying a gentle braking action. The arrester device is of a secret nature. Note that the wires are not high enough to trip the plane



Giant Floating Hangar Carries Sixty Planes



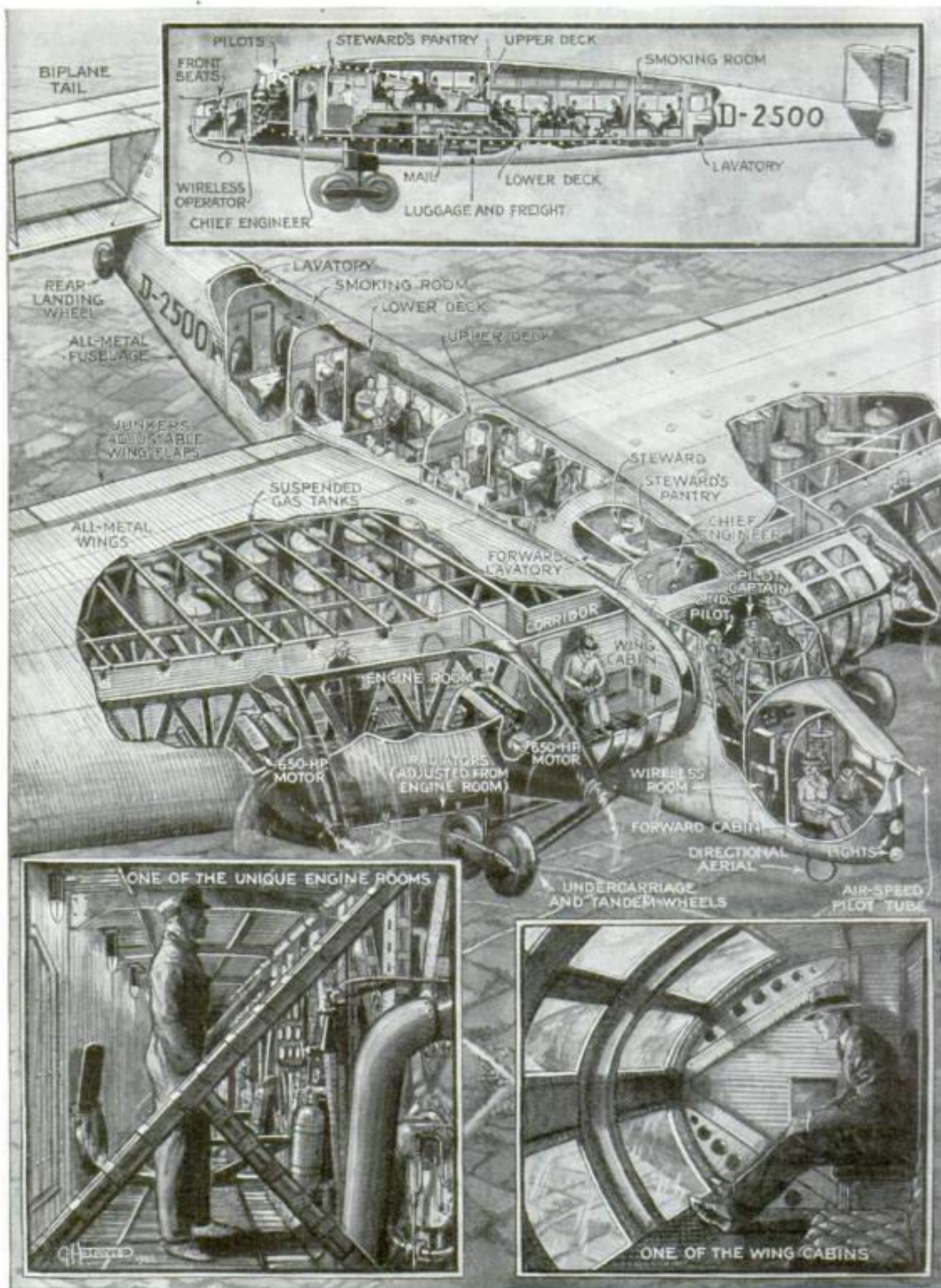
The "Ark Royal," literally a giant floating hangar, is 800 feet long and has space for sixty airplanes. The latest type of water-tube boilers and geared turbines, developing approximately 100,000 horse-power, give a speed above thirty-two knots. The flight deck extends the whole length of the vessel and has an enormous overhang at the stern, resulting in a bizarre appearance



Above and left, additional details of the carrier. Note position of funnel. Armament includes sixteen dual-purpose quick-firing guns, six groups of multiple pom-poms, eight groups of multiple machine guns and anti-torpedo and armor protection

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AMERICA'S NUCLEAR FLYING SAUCER

A trail of secret documents reveals the startling truth about the U.S. Air Force's flying disc aircraft.

BY JIM WILSON, Illustration by Tom Freeman



► In 1949, the biggest black hole in the universe wasn't in space, but across the Bering Strait. Stretching across 12 time zones, the Union of Soviet Socialist Republics was, as Winston Churchill would so memorably describe it, "a riddle wrapped in a mystery inside an enigma." The few things that most people knew about life behind the Iron Curtain seemed to be pieces of an incomprehensible puzzle. For the handful of intelligence experts who saw how

COVER STORY

the pieces fit, the "workers' paradise" presented a clear and present danger to the American way of life. What the intelligence community knew, and most people did not, was that in the final frantic hours of World War II, the Soviet army had hastily raided Germany's most advanced weapons research laboratories. And, on Aug. 29, 1949, only four years after Hiroshima, the technological booty from those raids turned a country whose farmers still used horse-drawn plows into a nuclear superpower.

The fireball of the communist atomic bomb cast a

sinister new light on an event that previously seemed quite inconsequential. In the summer of 1945, an unusual rumor had begun to circulate within the intelligence division of the European Command. During interrogations, captured German aircraft engineers referred to an extraordinarily fast rocket plane under development at a secret base in Bavaria. Unlike the Messerschmitt Me 163 rocket planes that had begun to attack Allied bombers in the last months of the war, this aircraft had an odd-looking curved wing that blended into its fuselage. The aerodynamic advantage of this configuration had been known to American designers for more than a decade. It created more lift than a standard wing, especially at low speeds, and provided more internal capacity for carrying bombs. In the early days of the war, the U.S. Navy had briefly experimented with circular wing design for those very reasons.

Anticipating that the first generation of communist atomic bombs would be as heavy as those America had dropped on Japan, it seemed reasonable to U.S. defense planners that the Soviet air force, which then lacked a nuclear bomber, would try to adapt German disc tech-



From 300 miles in space, the LRV would be able to rain nuclear destruction on the Soviet Union, Red China and North Korea.

"The operational mission design is six weeks at an orbital altitude of 300 nautical miles."

nology. The United States was, after all, doing exactly the same thing with the V-2s and Nazi rocket scientists it had spirited away in Operation Paper Clip.

In our July 1997 cover story, "Roswell Plus 50," **POPULAR MECHANICS** detailed how Air Force interest in duplicating Nazi technology led to two American flying disc projects. Project Silver Bug sought to build a vertical take-off and landing aircraft. Project Pye Wacket was to create small discs for use as air-to-air missiles. Documents declassified since then point to a third secret project, a 40-ft. "flying saucer" designed to rain nuclear destruction on the Soviet Union from 300 miles in space.

The official designation for America's nuclear flying saucer was the Lenticular Reentry Vehicle (LRV). It was designed by engineers at the Los Angeles Division of North American Aviation, under a contract with the U.S. Air Force. The project was managed out of Wright-Patterson Air Force Base, in Dayton, Ohio, where German engineers who had worked on rocket plane

and flying disc technology had been resettled.

The LRV escaped public scrutiny because it was hidden away as one of the Pentagon's so-called "black budget" items—that is, a secret project that is incorporated into some piece of nonclassified work. On Dec. 12, 1962, security officers at Wright-Patterson classified the LRV as secret because: "It describes an offensive weapon system." The project re-

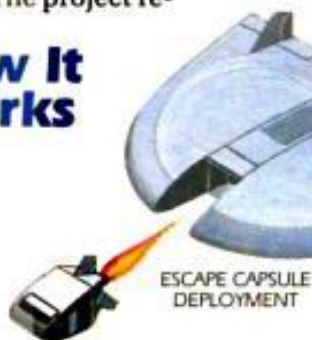
on orbit. There are repeated references to the LRV launching weapons-carrying clusters.

A considerable part of the design study focuses on the details of building a 40-ft.-dia. airframe and strengthening it against the acceleration of 8 g's and wind shear it would experience during launch. However, no mention is made of the type of booster the disc would ride into space.

Most likely, the LRV would have flown atop a multistage rocket, like the Saturn booster used in the Apollo moon program. The engineering study, however, suggests a more intriguing possibility. At some point, the LRV could have been powered by one of the nuclear rockets then under development by the Air Force and the Atomic



How It Works



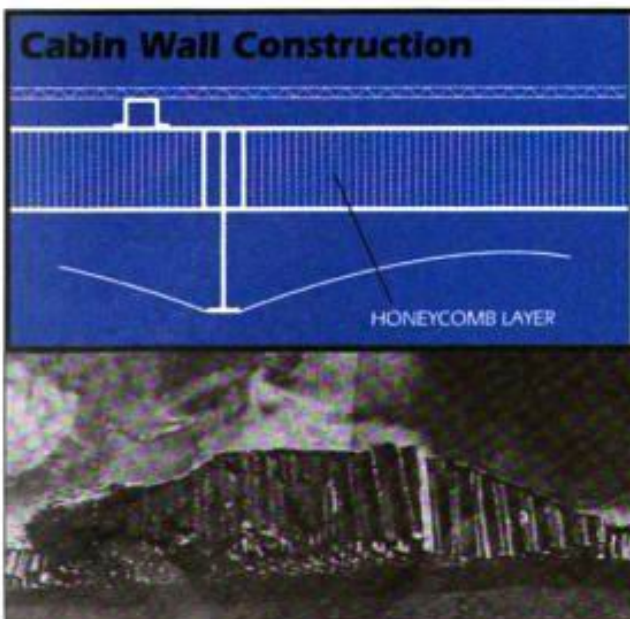
In normal operation, the LRV would use its saucer shape to dissipate re-entry heat and then provide lift for atmospheric flight.

mained classified until May 1999, when a congressionally mandated review of old documents changed the project's status as a government secret, downgrading it to public information. The Department of Defense did, however, successfully seek to have the document's distribution restricted to defense contractors. PM obtained its copy as the result of a Freedom of Information Act request.

Inside The LRV

"The operational mission design is six weeks' duration at a nominal orbital altitude of 300 nautical miles, with a crew of four men," according to the report. The weapons bay would hold "four winged weapons" that could be either launched or detached and parked

on orbit. There are repeated references to the LRV launching weapons-carrying clusters. A considerable part of the design study focuses on the details of building a 40-ft.-dia. airframe and strengthening it against the acceleration of 8 g's and wind shear it would experience during launch. However, no mention is made of the type of booster the disc would ride into space. Most likely, the LRV would have flown atop a multistage rocket, like the Saturn booster used in the Apollo moon program. The engineering study, however, suggests a more intriguing possibility. At some point, the LRV could have been powered by one of the nuclear rockets then under development by the Air Force and the Atomic



The materials recovered from the Fraser farm bear a striking resemblance to LRV engineering drawings.

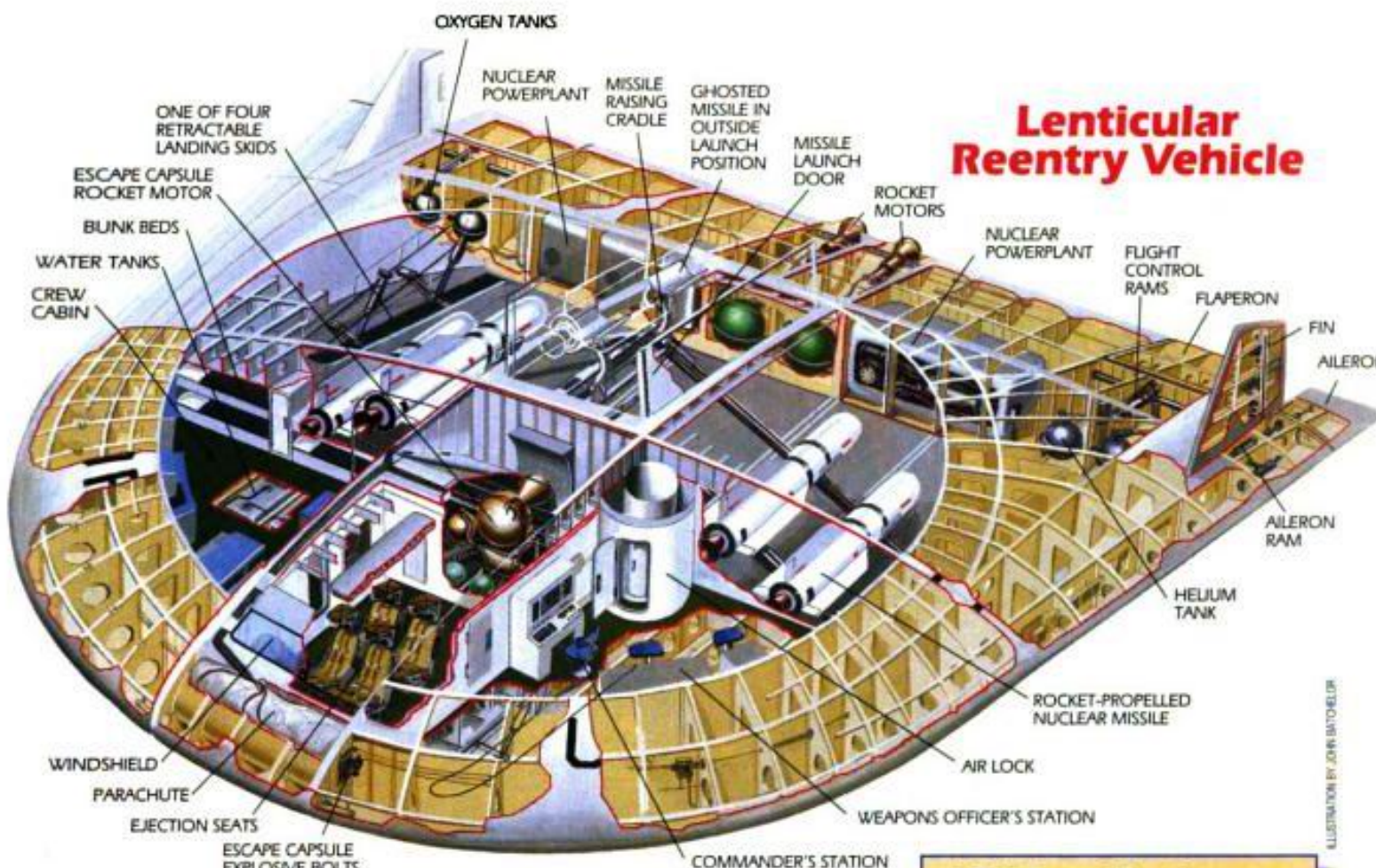


ILLUSTRATION BY JOHN BATOHELUP

Alamos, N.M. A DOE spokesman told PM that the only reason these records would have remained classified was if they dealt with an operational military system.

The four-man crew would ride a wedge-shaped capsule built inside the LRV. The capsule would divide the front portion of the disc into separate work and off-duty areas. The nuclear-tipped rockets would be stored in the rear segments.

Although these rockets were not called multiple independent reentry vehicles (MIRVs), they match the description of these multiple-warhead-delivery devices, which were later banned by disarmament treaties. An MIRV-equipped LRV would have been able to eliminate the war-making capabilities of the Soviet Union, China and North Korea at the push of a button.

In normal operations, the capsule would function as the LRV's flight control center. In an emergency, the crew could fire the capsule's independent 50,000-pound-thrust solid-fuel rocket motor and return to Earth. The capsule's final descent would be slowed by a parachute, much like the X-38 "lifeboat" planned for the

international space station now under construction.

A textbook mission would conclude with the entire LRV returning to Earth. It would fire its nuclear or liquid-fueled main rocket to brake, then travel edge-first into the atmosphere. Its disc form would dissipate the heat of re-entry, then act as a wing. Its flattened tail structure would provide directional stability and control. A minute or so before landing, skids would extend and the LRV would settle onto a stretch of dry lakebed.

The engineering study does not describe how the LRV, which would weigh just over 17,000 pounds without its crew, weapons, fuel and stores, would then have been returned to the launch pad. One possibility, suggested by the inclusion of a high-pressure helium storage tank, is that it would have been ferried by a heavy-lift balloon, as shown in the drawing on the opposite page. While the LRV would not have had sufficient helium to inflate a balloon, the tank would have

Lenticular Reentry Vehicle

LRV Specifications

Crew	4
Weapons	4 nuclear missiles
Mission Length	6 weeks
Dimensions	
Diameter	40 ft.
Center	90 in.
Edges	6 in.
Wing	1548 sq. ft.
Weights	
Launch	45,000 lb.
Landing	33,395 lb.
Empty	17,042 lb.
Engines	
Booster	Chemical/Nuclear
Main	Hypergolic/Nuclear
Capsule	Solid fuel
Electric Power	7 kw (thermal nuclear)
Designer	North American Aviation

had sufficient capacity for replenishing the lift-bag to permit trips of several thousands of miles.

In 1997, as part of its effort to debunk the Roswell alien landing myth, the Air Force revealed details of several heavy-lift balloon research projects. Among those were experiments in which 15,000-pound payloads were lifted to 170,000 ft. While not specifically acknowledging the

LRV by name, an Air Force spokesman conceded that during the Cold War it routinely used high-altitude balloons to

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ASTRONAUTS IN DANGER

NASA is banking on an untried emergency maneuver as it counts down to some of the most dangerous missions in space shuttle history.

BY STEFANO COLEDAN
Illustrations by Mark McCandlish

One of NASA's worst nightmares comes down to four letters: RTLS. Short for "return to launch site," it's a terrifying somersault in the sky that the space shuttle pilots would have to perform if a serious emergency, such as an engine failure, struck in the seconds after

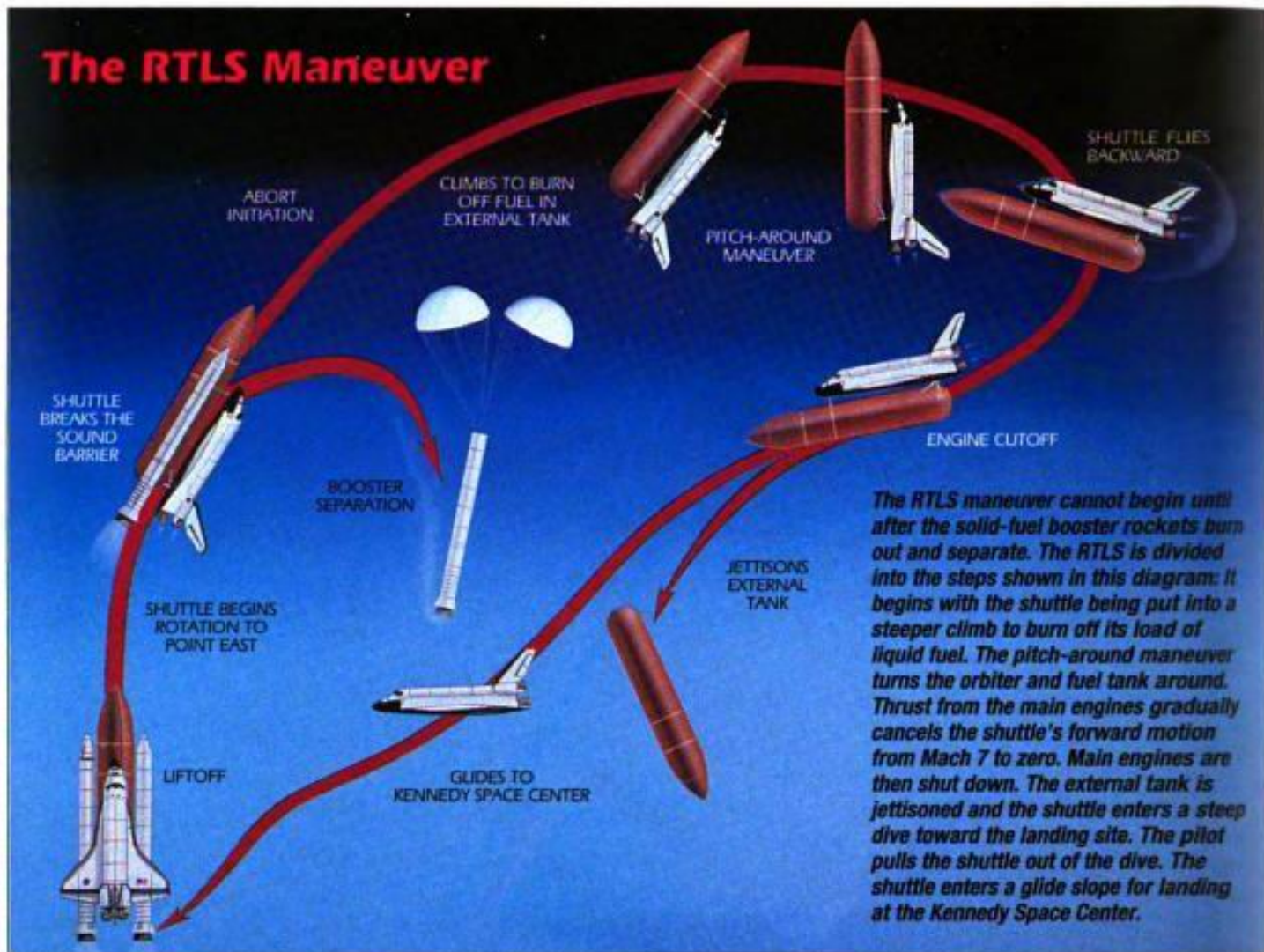
COVER STORY



liftoff. The RTLS maneuver involves flipping the 500-ton orbiter and half-empty fuel tank 180° while flying at nearly seven times the speed of sound, then gliding the stubby-winged orbiter to the Kennedy Space Center runway. Space shuttles have flown 100 times, and so far astronauts have never been confronted with an RTLS. However, two seemingly unrelated factors make some of the

upcoming flights the riskiest in the space station construction program. The first involves the payload—the U.S. laboratory module, *Destiny*—which is to be attached to the International Space Station. Weighing 30,000 pounds, it will be one of the heaviest pieces of cargo ever carried by a shuttle. The second factor involves shuttle preparation technicians. Blaming cutbacks, the U.S. General Accounting Office has

The RTLS Maneuver



The RTLS maneuver cannot begin until after the solid-fuel booster rockets burn out and separate. The RTLS is divided into the steps shown in this diagram: It begins with the shuttle being put into a steeper climb to burn off its load of liquid fuel. The pitch-around maneuver turns the orbiter and fuel tank around. Thrust from the main engines gradually cancels the shuttle's forward motion from Mach 7 to zero. Main engines are then shut down. The external tank is jettisoned and the shuttle enters a steep dive toward the landing site. The pilot pulls the shuttle out of the dive. The shuttle enters a glide slope for landing at the Kennedy Space Center.

described the shuttle team as "showing signs of overwork and fatigue" and cautioned that the margin of safety has never been thinner. These concerns raise the question of whether an RTLS is more likely to occur than ever before.

Surprisingly, even among astronauts there is doubt that the unforgiving maneuver would be survivable. "The first person that does one will be able to tell you whether it works or not," says John Young, a NASA veteran who walked on the moon in 1972 and commanded the first shuttle mission in 1981. "We have never done a powered pitch-down separation at Mach 6.7, very rapidly. Theoretically, it will work, but practically, will it work?"

Flying The RTLS

Ideally, here's how an RTLS would work if the shuttle encounters one of six major failures that would dictate an immediate landing. These include a failed engine, fuel leaks, pressure loss in the cabin, or a major leak of Freon gas from the cooling system. At this early point in a flight, the shuttle must continue

its ascent toward space so the twin boosters can burn off their supply of solid fuel. The boosters separate 2 minutes into the flight. A half-minute later, the pilots turn a rotary switch in the cockpit to the RTLS abort position.

Initially, the shuttle continues to fly away from Florida to use up about half of the highly explosive liquid hydrogen fuel and oxygen in the rust-colored external tank. At an altitude of about 40 miles, the most difficult and dangerous part of the maneuver begins. It is called a pitch-around. As the shuttle is still flying over the Atlantic in the normal upside-down position, the on-board computers pitch the shuttle's nose up under pilot supervision. Gradually, the ship turns around until its nose is pointed toward Florida. With its engines firing and acting as brakes, the shuttle streaks backward—tail first—at seven times the speed of sound. This makes the craft slow down and lose altitude as it flies into its 5000° F exhaust plume.

"This is something you can't even test in a wind tunnel, so the testing has been done by analysis," says

Kenneth Cockrell, commander of the upcoming *Atlantis* flight. "The first crew to do it—if it should ever happen, and hopefully it won't—would be along for quite a ride."

Once the propellant reserve drops to about 2 percent, the shuttle's external tank is discarded with little risk of it bouncing against the craft. Then the shuttle gains speed again, and it can be rather challenging, Cockrell says. The flight ends 6 or 7 minutes later in a way similar to a normal re-entry from orbit. "If everything works perfectly, we will do just fine. And if everything doesn't work perfectly, it probably won't be too good," Young says.

Close Call On Columbia

But what would happen in a less-than-perfect scenario, such as a multiple engine failure or when the shuttle is carrying one of the heavier pieces of the space station? "If you fail more than one engine when you're way up high, you fall out of the sky," says Young. A combination of speed and high deceleration forces would be too much for a shuttle to hold together. "And that



WINGS OF MERCY

A new flying eye hospital promises sight for the needy and medical skills for the developing world.

BY WILLIAM GARVEY; PM Photos by Brian R. Wolff

● **Fact:** More than 42 million people in the world are blind. For most of those people, proper treatment can cure their blindness or could have prevented it.

Fact: 90% of the world's blind live in developing countries where resources are lean and eye-care services lag behind those in richer, industrialized nations.

Fact: The situation is tragic and worsening.

The obvious solution to these problems is to get modern ophthalmologic care where it is most needed. Far less obvious is how to accomplish that goal and to make up-to-date eye care a permanent reality in regions where it does not now exist.

Enter Orbis, an eye-care teaching hospital on wings. A nonprofit operation dedicated to fighting blindness worldwide, Orbis travels to virtually any country whose ophthalmological society extends it an invitation. The aircraft touches down with a full complement of staff doctors, nurses and technicians, as well as a revolving group of practicing ophthalmologists. During each 3-week mission, this volunteer faculty provides hands-on instruction to the local medical community.

The value of an Orbis visit is inestimable—what is a blind child's first glimpse of her mother worth?—but it comes without charge. Not a nickel.

Orbis began in 1982 with a converted Douglas DC-8 donated by United Airlines. In a dozen years, that air-



Orbis's mid-fuselage operating room doubles as a learning theater for eye surgeons, who can watch through picture windows.

craft provided training for 28,000 doctors and nurses and restored the sight of 18,000 patients in 70 countries. Then the oldest DC-8 in operation, it has now retired to a museum in China. And it's been succeeded by a McDonnell Douglas DC-10 unlike any other.

The new aircraft embodies mechanical contradiction. A teaching hospital, it is also a jumbo jet. Crammed with gear, it accommodates crowds comfortably. It contains highly advanced, supersensitive devices, yet it is virtually self-sufficient, able to function at its peak in the most desolate places.

Satisfying those contradictions required more than three years for planning, design, stripping, overhaul, manufacture and installation. The Orbis conversion—



The audiovisual room produces videos to teach new procedures, while satellite-communications dish serves Orbis in remote locations.

a \$10-million job for which the Orbis International organization is still raising money—took place at Mobile Aerospace Engineering in Alabama.

The gleaming new jet emerged last spring. Today, the flight deck and forward fuselage seem unchanged from its airline days. The cockpit is crisp but standard. Behind it, the passenger compartment looks like a typical coach configuration. But first impressions can be misleading: This is not the 4:30 shuttle to Washington.

First-class education

The passenger cabin is actually a high-tech interactive classroom. Up front lies a presentation area for large-screen film, slide or chalkboard visuals. To record lectures, video cameras stud the cabin's walls. In addition, several TV monitors provide for live and taped broadcasts. And while the monitors show an ongoing eye operation, the seated attendees can use the cabin's microphones to converse with the surgeons.

Immediately aft of the classroom is the audiovisual room. Here, Orbis personnel monitor and direct the aircraft's 17 cameras, all broadcast-quality Sony Betacam SPs. Videotape plays an invaluable role. The staff has created a library of more than 150 tapes on eye surgery and treatment, which it distributes during each mission.

Re-engineering an airliner to carry a welter of electronics wasn't easy. The wiring alone weighed so much that engineers feared it might overstress the floor. Consequently, during the plane's conversion, the bundles were split with some supported by the floor and the rest suspended from the ceiling.

Continuing aft along the single port-side aisle, you next encounter the laser/exam room. Here, physicians can diagnose diseases such as cataracts, trachoma, glaucoma and river blindness. Doctors can often rectify the disorders using the aircraft's argon, YAG and solid-state lasers. As in all the rooms aboard the aircraft, video cameras record procedures and transmit them to the classroom.

Moving farther rearward, you come to the jet's multifunction conference room. When Orbis arrives, it invariably attracts media and VIPs (everyone from Mother Teresa to Fidel Castro toured the old DC-8), and this is where the heavy hitters are briefed on the DC-10.

On-board operations

Back in the aisle, you'll move all the way down to the rear of the aircraft.

There, a doorway on the left opens into another large room. Three gurney beds jut out from the right wall. Each is surrounded with heart/blood-pressure/temperature monitors, intravenous trees, oxygen ports and similar post-operative patient gear.

If you've ever had surgery, this is familiar turf:



Welcome to the recovery room, albeit with a long row of airliner windows. Here, patients are prepped for surgery. Then the gurneys wheel forward through swinging doors into the substerile area, where medicines are prepared, surgical utensils are sterilized and doctors scrub.

Continuing forward, more swinging doors lead into the operating room. Planted between the wings—the most



The exam room features stereo microscopes and lasers, while patients receive pre- and post-operative care in aft recovery room.



The classroom is the heart of the Orbis mission, where traveling ophthalmologists share knowledge with local physicians and nurses.

stable part of the aircraft—the room rests on reinforced flooring. And it's as advanced as any ophthalmological OR you'll find on the planet.

At the center of the room is a Zeiss operating microscope, employed for such procedures as corneal transplants. The room is festooned with cameras (including one within the microscope) that transmit the proceedings onto monitors. Picture windows permit VIPs and others to view the medical procedures without crowding into the operating theater and compromising sterility.

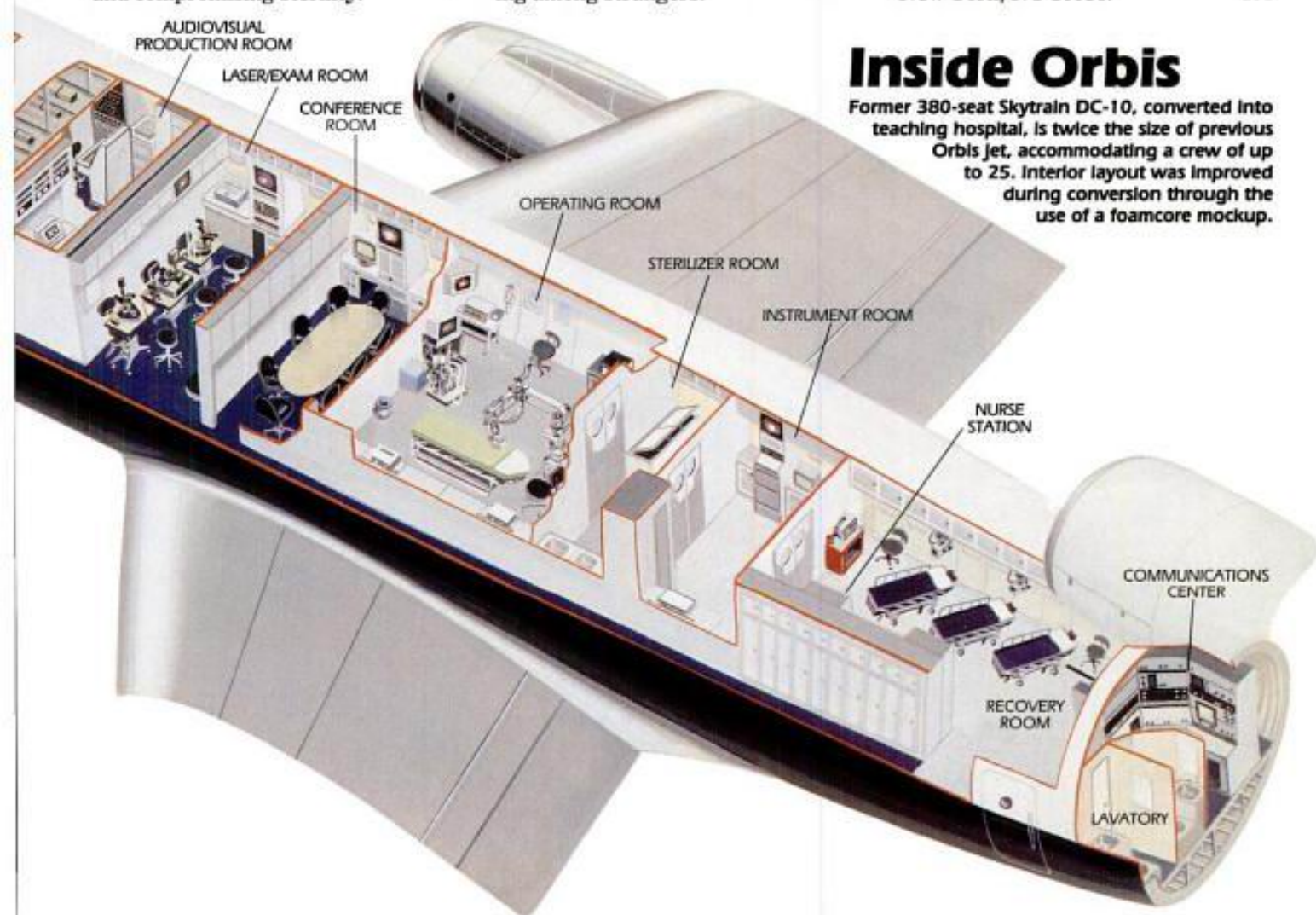
Meanwhile, belowdecks in the cargo hold are six standard LD-3 containers, modified specially for Orbis. Three of them house diesel generators—two for electricity and one for air conditioning—which deploy on the ground when necessary. The aircraft can also plug into any local power source.

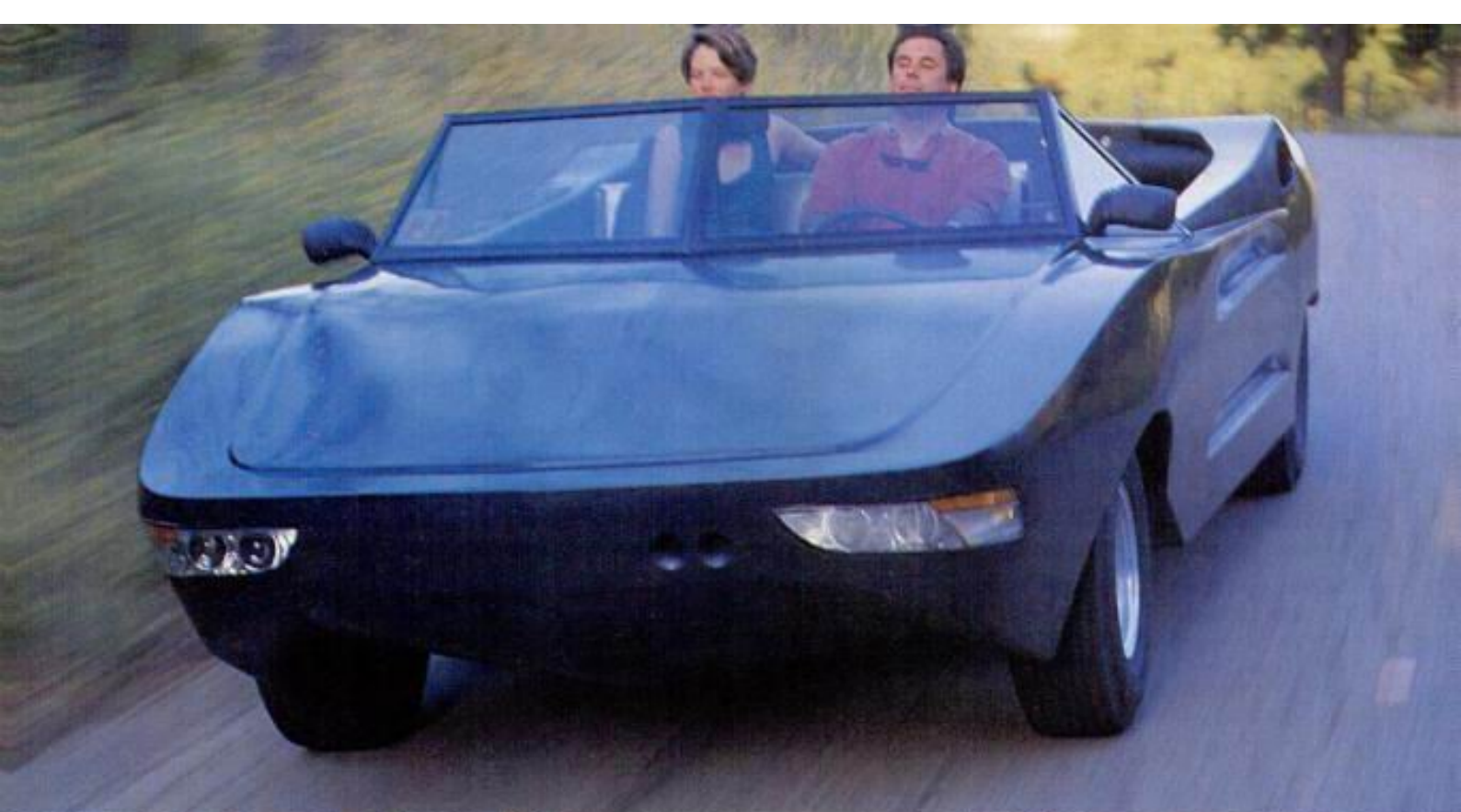
Much more than a collection of mechanical components, however, Orbis represents the best of humanity: It encompasses technical genius as well as selfless assistance to relieve suffering among strangers.

The \$14-million purchase price of the DC-10 was covered by donations from FlightSafety International founder (and Orbis's unpaid chairman) A.L. Ueltschi, Hong Kong businessman Y.C. Ho and one anonymous contributor. But to keep flying, Orbis depends exclusively on the generosity of those who can give—money, material, services or time. If you'd like to learn more about Orbis's work, or if you're interested in contributing in some way, contact Orbis International, 330 W. 42nd St., Suite 1900, New York, NY 10036. **PM**

Inside Orbis

Former 380-seat Skytrain DC-10, converted into teaching hospital, is twice the size of previous Orbis jet, accommodating a crew of up to 25. Interior layout was improved during conversion through the use of a foamcore mockup.





A split personality: The Aquastrada Delta keeps company with sports cars and sport boats. Shift-on-the-fly capability enables the Delta to engage the jet pump with the push of a button while rolling down the launch ramp.

AQUASTRADA

Fast on land, fast in the water. This new car-boat is what the Amphicar should have been.

BY JOE SKORUPA, Boating/Outdoors Editor
PM Photos by George Olson

● To a kid in the early 1960s, the Amphicar was the coolest car in town. Well, one of the coolest. Remember the Amphicar? It was a little convertible import (called a foreign car back then) that ran on land and water. It performed neither operation well, but it caused quite a stir when driven down the launch ramp and into the water.

Today, the West German-built Amphicar is a curious footnote in automotive history. It ceased production in the 1970s, but the dream of a dual-medium vehicle has never died.

There have been several attempts to build a better Amphicar in recent years. Two that come to mind are the French-built Hobbicar and the German-built Amphi-Ranger—neither of which made much of a splash.

The most recent entry has a better shot at succeeding. It's called the Aquastrada Delta, an amphibious vehicle built by a group of entrepreneurs from Northern California. Like a typical Silicon Valley skunk-works project, the model tested for this story is a proof-of-concept vehicle that's been assembled on weekends and nights by a dedicated team of gearheads. Heading up the team is designer Gary Gere, a staff engineer at Sun Microsystems.

Gere began the Aquastrada project with a simple idea: Instead of building a car with marine capability, build a car that's really a boat.

This is a completely different approach than that taken by Hans Trippel for the Amphicar. The Amphicar was not only underpowered for the road (with its 43-hp 1.2-liter 4-cylinder Triumph engine), but it had a top speed of about 5 mph in the water. For an old road-racer like Gere, any vehicle worthy of a wrench has to be fast. In this case, fast on land and fast on water.

To accomplish this feat, Gere started with a truck engine—a marinated 351-cu.-in. 245-hp Ford Windsor block. To this he mated a Ford C6 truck transmission. From here, things get creative.

The Amphicar achieved marine

propulsion by running two prop shafts out of the transfer case. Steering was controlled (suggested, really) by using the front wheels as rudders.

Gere improves on these systems by using a Dominator jet-pump engine instead of props. This not only delivers impressive thrust, but swivels from side to side to achieve true marine steering.

Power is delivered to the jet pump through a Ford Bronco 4wd transfer case, which is installed upside down. The shaft normally used for 4wd gearing now runs to the jet



Ford truck engine, transmission and transfer case comprise the powertrain.

pump. At the push of a button, the Delta goes from 2wd to jet drive, or both. For steering, a standard rack-and-pinion unit is fitted with cables that run to the jet pump. The result is that steering on land and water is accomplished by using the same wheel.

Externally, too, the Delta is a different animal than the Amphicar. The body is basically a standard fiberglass hull made with a layer of foam coring for stiffness and a shallow-V bottom for improved tracking and getting up on plane.

Without doubt the crowning achievement of the Delta is a retractable sus-

pension that pulls the wheels up and into the hull. This system accomplishes its unique feat by using split axles and a sleeve-and-rail structure connected to the suspension mounting arms. Pneumatic servo units pull the suspension arms inward, which has the effect of raising the wheels into dedicated compartments. In this position, seals make the wheel wells watertight.

The Delta had no trouble maintaining passing speed on the freeway south of San Francisco. On the water, it was able to plane and keep up with sport boats on a busy recreational lake. Performance is estimated to be 100 mph on land and 45 mph on water for production vehicles.

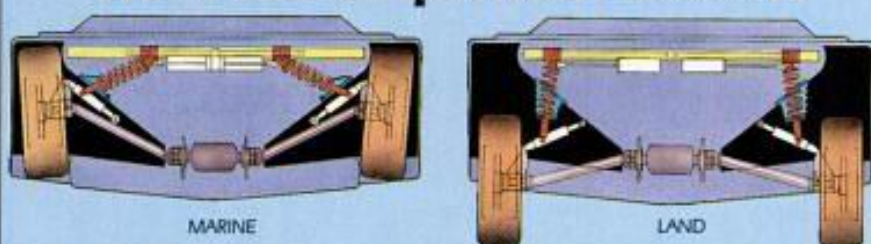
Much will change when the Delta moves into production models in the coming months, but the specifications are projected to be as follows: weight: 2830 lb., length: 222 in., width: 93 in., wheelbase: 139 in., ground clearance: 10 in., draught: 6 in., free board: 30 in., retail price: \$25,000 to \$35,000.

For anyone interested in finding out more about the Delta, contact Bei Ming Wang, president of Aquastrada, at 25 E. Carmel Valley Rd., Carmel Valley, CA 93924, or call (408) 644-8091.

Interestingly, I came across an Amphicar in Seattle on a recent trip. The owner called it one of the best-preserved models in the country. He said, "I drove it last year. It ran great. Would you like to buy it?" Being polite, I said, "Not right now. Maybe later." "It may not be here later," he added. "There's nothing like it." Nothing except the new and improved Aquastrada Delta, but I didn't have the heart to tell him.

PM

How The Suspension Retracts



Pneumatic rams slide suspension arms inward and lift the wheels into the hull.

PM ILLUSTRATION BY RON CARSON

JOURNEY TO THE CENTER OF THE EARTH

Drilling miles into our planet's crust, engineers are pushing the frontiers of technology and geology.

BY GREGORY T. POPE
PM Illustrations by Jeff Mangiat

● Earth's face is familiar, but what lies beneath those superficial features? No one knows—no one's been down there. Theories about our planet's inner self emerge strictly from experiments carried out on the surface. But geologists aren't satisfied with indirect evidence. They want to peer right into the bowels of the Earth for a first-hand look.

To do that means to drill miles into the planet's crust, opening geology's final frontier. Such super-deep holes—dubbed “telescopes into the Earth” by their creators—challenge the limits of drilling technology. Engineers must send machines into a hellish environment, hemmed in by high pressure and hard rock, and riddled with hot, corrosive fluids.

So far, the Soviet Union has shown the most interest in meeting this challenge, with plans to complete 11 exploratory shafts by the year 2000. The deepest so far, on the Kola Peninsula, east of Finland, has now plunged well over 7½ miles. The Soviets say they won't stop until they're nearly 9 miles down. Meanwhile, a new shaft in the Ural Mountains will surpass the Kola hole sometime in the mid-1990s. Germany has also embarked on a superdeep project, aiming to bore 6½ miles under the Black Forest.

The United States, constrained by skimpy budgets, has avoided getting caught up in a race to inner space. The deepest that scientific drillers have ventured here is 11,515 ft., at Cajon Pass on the San Andreas Fault. Instead of burrowing headlong into the depths, Americans target geological hot spots, such as the fault and the volcanoes of California and Alaska. These well-aimed holes guarantee big scientific pay-offs.

Nevertheless, the Soviet and German sites attract

German KTB drill navigates miles into the Earth with hydraulically powered steering runners, controlled by inclinometers and electronics. Electricity to power cutting head and hydraulics comes from mud-driven turbine generator.



JOURNEY TO THE CENTER OF THE EARTH



The unguided Kola drill wandered as much as 2700 ft. off vertical as it bored through granite-based crust, penetrating near-surface ore deposits, two deeper ore strata and a layer of shattered rock.

hundreds of American scientists each year. Not only have the boreholes pioneered superdeep technology, but they're forcing researchers to rewrite the rules of geology.

Kola miners

A good example is the Soviet hole at Kola, now in its 21st year. In the mid-'70s, the Kola rig was supposed to plunge through the legendary Conrad discontinuity, thought by geophysicists to be the interface between the granite-based middle crust and basalt-based lower crust. Their evidence: seismic surveys, in which experimenters send sonic blasts into the ground, then time echoes from underground rock layers. By analyzing the change in sound-wave speeds, researchers calculated that the granite-basalt border lay $4\frac{1}{2}$ miles down. But today, the Soviets are miles below that level and have yet to hit basalt.

"In reality, we did not find a physical border," says Boris N. Khakhaev, mastermind of the Soviet superdeep program. Director general of the quasi governmental deep-drilling outfit NEDRA, Khakhaev spoke with POPULAR MECHANICS by telephone from his home in Yaroslavl, 150 miles northeast of Moscow. "This hole," he adds, "drastically changes our concept of deep structure in the Earth." Instead of marking the basalt border, geologists now surmise, the phenomenon found by the seismic surveys may be the roof of a granite sublayer shattered by water that was squeezed from shallower strata.

Not only has the Kola hole undermined geological assumptions, but the project is also showing drillers how unforgiving Mother Earth can be. Emergencies are frequent, admits Khakhaev. The most recent came last November when loose rock $7\frac{1}{2}$ miles down crushed the interlock between two lengths of drill pipe, pinching off the shaft. "The fact is," he says, "that at very low depths, crystalline rocks are quite unstable and subject to collapse"—another scientific surprise.

One lesson learned at Kola is the importance of sinking as straight a shaft as possible. The Kola hole corkscrews into the ground, meandering as far as 2700 ft. off the vertical. The curvature puts dangerous strain and wear on the drill pipe. In NEDRA's two newest superdeep holes, Khakhaev's crews address the problem with a 2-pronged, gyroscopically stabilized drill bit. Each of the bit's twin-

cutting heads is powered by a separate turbine motor that follows it down into the hole. These downhole turbines are themselves fixed to an assembly that spins with enough angular momentum to keep the whole drill vertical.

Stay the course

Having witnessed the Soviet tribulations at Kola, Germany has sunk a major technological investment into its superdeep project, the Kontinentales Tiefbohrprogramm (KTB) in Bavaria. Instead of a passive steering system like the Russians', German engineers have built active navigational equipment into their downhole assembly.

Behind the cutting head, inclinometers detect any deviation from the vertical. The sensors then trigger one of four hydraulic pistons to push a runner against the side of the shaft, forcing the cutter back on course.

"One thing we've learned from the Russians is that we have to use these systems at shallow depths," says Peter Kehrner, project co-director with Germany's Geological Survey of Lower Saxony, "because if we don't keep vertical at those levels, we'll never make it." To that end, drillers first bored a shallow test hole to 13,120 ft., coring the rock for later analysis. Now that the KTB hole is under way, drillers can concentrate on staying vertical to the depth of the test hole and save the coring for the unprobed deep layers.

While the Germans' steering systems are new and experimental, their strategy for retrieving the downhole assembly is more conservative.

Superdeep drillers must periodically pull their machinery to the surface to replace drill bits and empty the core barrel of rock samples. Traditionally, this involves "round-tripping," driller lingo for yanking the whole drill pipe out of the shaft. In the Soviet Union, NEDRA developed an ingenious way of flushing the assembly out of the hole. Operators reverse the flow of drilling mud, a polymer-based fluid that's pumped through the drill pipe to drive a downhole turbine and cool the cutting head. Flowing backward, the mud propels the downhole machinery to the surface.

The Germans have chosen to stay with the foolproof, if time-consuming, round-tripping approach. To speed the process, surface-rig robots quickly unscrew, examine and stack pipe lengths as they emerge from the hole.

Just like their Soviet counterparts, the German drillers have met some surprises. The KTB hole marks the spot where two continental plates collided and fused 350 million years ago.

Sandia's Long Valley Caldera drill sits atop a volcano that last erupted 700,000 years ago, with several thousand times the force of Mount St. Helens. The drill will probe toward molten magma, a potential energy source.

Seismic surveys had suggested that rock layers from each plate overlapped horizontally at the suture. But once again, drilling revealed a different picture: The collision triggered folding and buckling that jackknifed rock layers almost vertically.

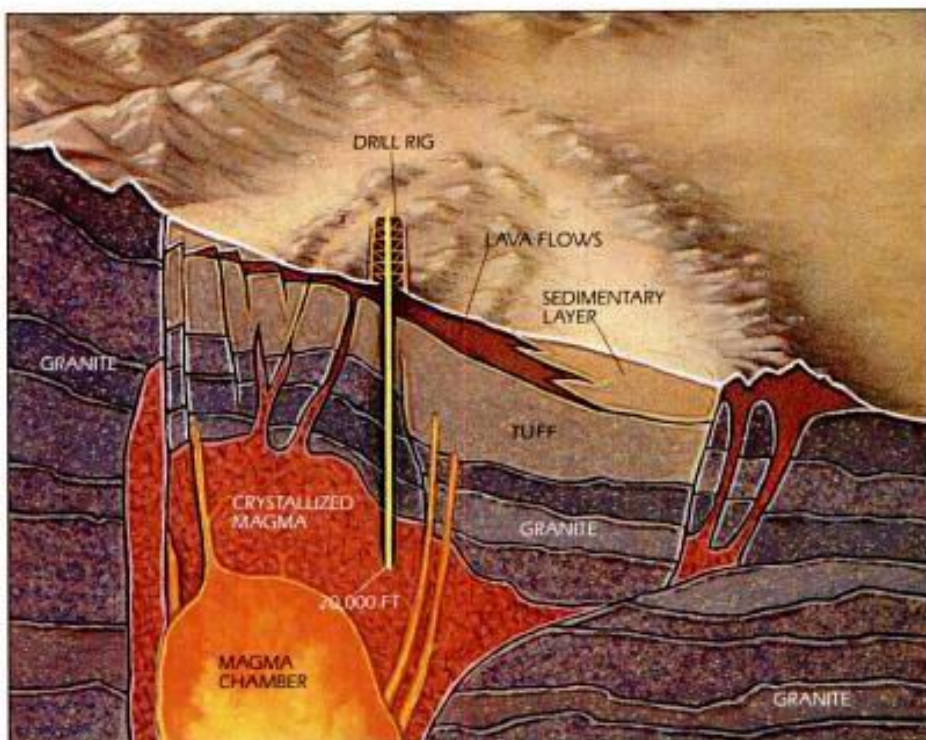
More alarming was the suture's high temperature. Last year, when drillers completed the test hole, they gauged the temperature at the bottom to be a toasty 244° F—almost 72° higher than expected. Since the Germans aren't about to push their equipment past 572° F, the discovery means that the KTB hole must stop several miles short of its original goal.

Holes for heat

By contrast, drilling into scalding temperatures is precisely the goal at several locations in the United States. The hottest among current projects lies near the California/Nevada border. The site is the Long Valley Caldera, a collapsed volcanic crater that probably caps a huge reservoir of molten rock, or magma.

Unlike the Soviets and Germans, Long Valley drillers from Sandia National Labs aren't taking continuous core samples. They're seeking simply to verify the magma's existence. Lacking core-barrel equipment, with its elastomeric seals and other heat-sensitive parts, the Long Valley drill can push on until temperatures hit 932° F—possibly as far as 20,000 ft.—creating the deepest scientific hole in the U.S.

Should drillers find the magma,



step two would be to drill a second hole straight into the 1000° F rock and tap the heat to power steam generators for geothermal energy. To penetrate the magma chamber, waterjets will probably blast ahead of the drill bit, chilling the molten rock before cutting into it. Converting the magma's heat to energy, however, will call for equipment not yet developed. Meanwhile, geologists are now digging through a landslide of data from a 5370-ft. hole at Valles Caldera in New Mexico, completed in 1988. The project explored a complex volcanic system that last blew its top 600 years ago. It is America's hottest, deepest continuously cored hole.

Temperatures at the bottom hit 563° F, a trial by fire for hot-drilling

technology. Engineers had to ad-lib as problems arose, at one point tossing iron bolts into the hole to sharpen the cutting head. But the project was completed on time and within budget, proving that scientific drills can handle fiendish temperatures. "Right now we could easily go to 650° to 750°," says Sandia project director Peter Lysne.

Why subject expensive equipment to such punishment? Volcanoes, geologists say, remain one of Earth's most mysterious—and threatening—features. "These are tremendously powerful and dangerous systems," says Sandia geochemist John Eichelberger, "and we have a wealth of hypotheses but little direct observation."

PM



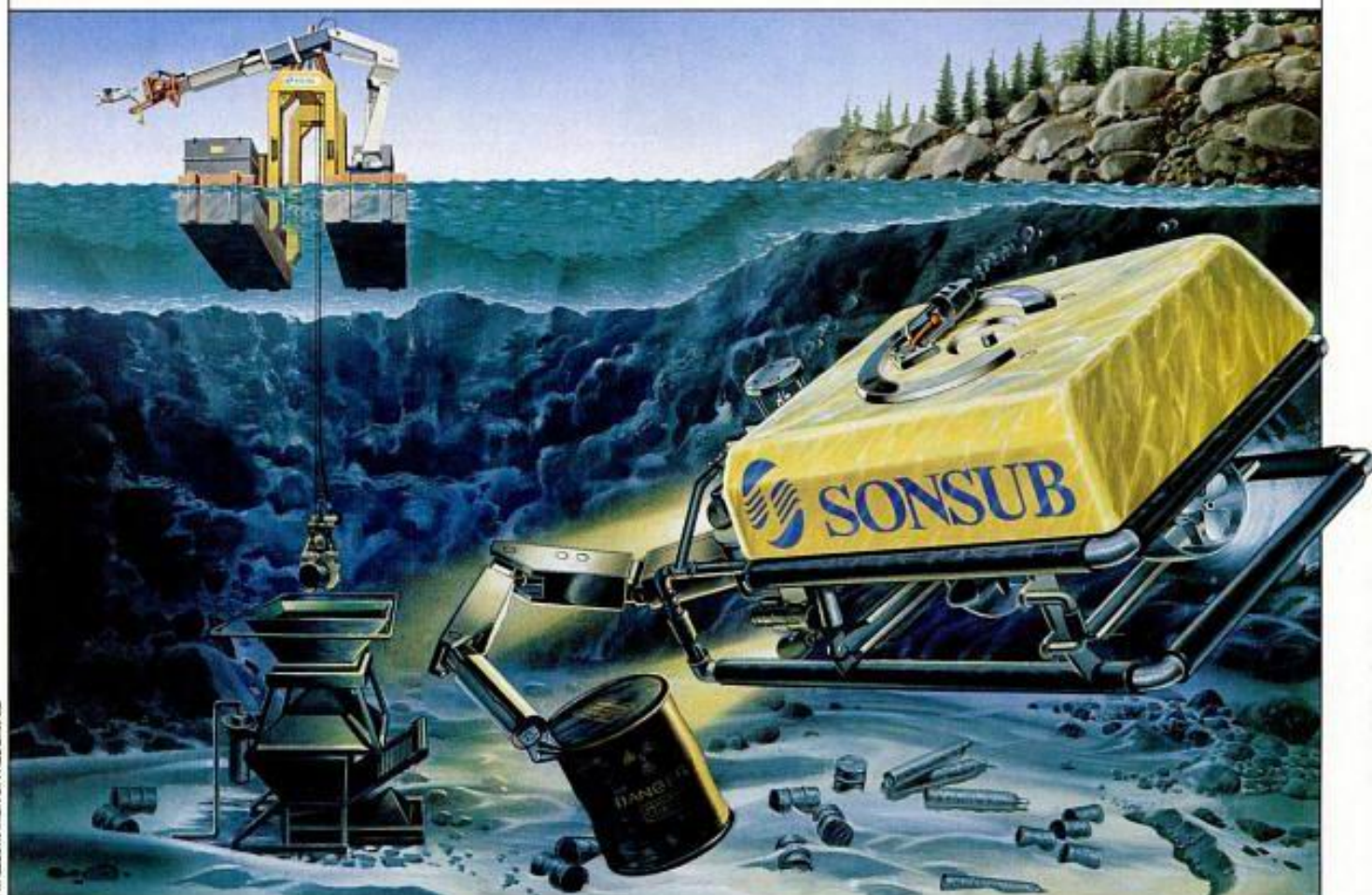
Kola rig (left) pioneered superdeep technology, now being applied in new Urals rig (above). German KTB rig (right) employs robotic pipe handling for fast round-tripping.



(LEFT) G. ARTHUR BARBER PHOTO; (MIDDLE) JOHN EICHELBERGER PHOTO; (RIGHT) JAMES F. HAYS PHOTO

TECH UPDATE

News Of Tomorrow's Technology Today



PAUL CHAMBERLAIN

Shredding Robots Clean Up A Witches' Brew

OAK RIDGE, TN—Kerr Hollow is a setting straight from a B-grade horror movie. For decades, the Department of Energy filled this flooded quarry with radioactive clutter—including drums of liquid sodium and potassium, used as coolant in nuclear reactors. Not only is the liquid radiation-tainted, it's also spectacularly explosive.

Enter two intrepid robots. So far they've plucked out 17,000 objects, surviving a couple of blasts with little worse than singed paint jobs.

The machines aren't bringing the volatile material to the surface. That's just asking for trouble. Instead, they are feeding the drums into a

25-ton shredding machine at the quarry's bottom.

The shredder minces the drums into chips that tumble into a collection basket. The processing allows the liquid metal to burn up in water without detonating in bulk.

One of the robots is a modified Perry submersible vehicle, outfitted with an arm that can pick through debris, close the shredder's containment doors and bring the basket to the surface. The other is a barge equipped with a jointed arm and a grapple.

The project, engineered by Sonsub Environmental

Editor: Abe Dane
Writer: Greg Pope
Reporters: Philip Chien, Scott Gourley,
Ray Thurstby

Services, will serve as a model for other Energy Department cleanup efforts.

Submersible robot and grapple-handed surface barge feed and empty waste shredder.

Highlights This Month

- **Regular Or Super?**—Singular Russian rocket burns multiple fuels.
- **Bus Stop 2000**—Aerospace expertise turns to mass transit.
- **Saw Mole**—Latest tunnel-boring machine carves out arched passages.
- **Razzle-Dazzle Nozzles**—Thrust-vectoring F-16 starts flying.
- **Going With The Glow**—Satellite to test nuclear electric propulsion.
- **Weather Eyes**—New atmospheric satellites will fill in the blanks.

TECH UPDATE

News Of Tomorrow's Technology Today



PM ILLUSTRATION BY MARK MCANDOLPH

Soaring Drone To Shoot Down Ballistic Missiles

HUNTSVILLE, AL—High-altitude unmanned air vehicles are candidates for a variety of jobs, from relaying telecommunications to sampling our tainted stratosphere.

But the Strategic Defense Initiative Organization has drawn up its own role for high-flying drones: heaving high-speed projectiles at Scud-type missiles.

The proposal, as yet unfunded, scales down the Brilliant Pebbles scheme, which stars missile-packing, ICBM-targeting satellites. The idea is to intercept tactical missiles as they rise from their launchers.

While in this boost phase, a missile is easy to track because its rocket burns brightly and the missile itself hasn't

yet released decoys or shed debris. What's more, enemy missiles picked off in boost phase drop warheads on enemy territory.

To accomplish this task, the air vehicle, known as Raptor, would carry a battery of Theater-Application Launch-On-Notice, or Talon, weapons. These kinetic-kill missiles, fired vertically from Raptor's back, would chase down and spear their targets at a speed of Mach 4.

Raptor itself would be a solar-electric vehicle able to stay on station indefinitely.

Rear-echelon commanders would normally control Raptor but it could assume an autonomous operation if hostil-

ities broke out. And if one Raptor fell victim to a surface-to-air missile, another could quickly take its place.

The SDI Organization would like to test-fly some

High-flying Raptor volleys kinetic-kill vehicles at Scud missiles in boost phase.

hardware by the end of 1995, first using a turbocharged air-breathing engine.

Editor: Abe Danc
Assistant Editor: Greg Pope
Contributors: Philip Chien,
Paul Eisenstein, Mike Fillon

Highlights This Month

- **Maglev Revival**—Major new government effort to float locomotives.
- **World's Biggest BB Gun**—Gas-powered launch tube aims for space.
- **Robots' Battle Royale**—Top-10 automotons tussle for technical dominance.
- **Space Launch Stowaways**—NASA's rocket stages carry piggyback experiments.
- **Wheeled And Dangerous**—Army's robots can fend for themselves.
- **Radar Brakes**—Grille-mounted antenna to run cars' cruise control.

TECH UPDATE

News Of Tomorrow's Technology Today



ILLUSTRATION BY JEFF MORGAN

Convection Towers To Rinse Out Urban Smog

LOS ALAMOS, NM—People tend to picture chimneys as sources of soot, smoke and smells. But if one physicist has his way, a new breed of chimney could reverse that smokestack image by reversing air pollution.

Melvin Prueitt, of Los Alamos National Laboratories, believes that 500-ft. fabric-skinned towers could function as giant air purifiers. In Prueitt's scheme, water sprayers at each tower's top generate a fine mist that absorbs the pollution.

The air turns damp and cool and tumbles through the tower, creating a downdraft that draws more air into the top. At the tower's bottom, the air pressure turns wind

turbines to generate more electricity than the tower uses. The humid, clean air blows out radially, displacing the drier, dirty air upward.

Filter systems could cleanse the smog-laden water, and pumps could send it out to sea. Since the humidity level in the tower is 100%, sea water could be pumped in to clean the air without leaving salt deposits. That's good news for parched Los Angeles, which would need to muster a billion gallons of water a day to rinse out half its air.

Right now Prueitt's idea exists only in fluid-dynamics

studies and computer simulations, but he hopes to build a demonstration unit within five years.

Smog-plagued Los Angeles could benefit from 500-ft. convection towers that cleanse and humidify air.

Highlights This Month

- **Site Check**—Superdrill probes future atomic mortuary.
- **Kamikaze Probe**—Veteran spacecraft makes ultimate sacrifice for science.
- **One Tractor Mind**—Smart farm vehicles drive themselves.
- **Dish Watching**—Huge radio telescope gets facelift.
- **Head Lights**—Optical devices track brain oxygen during surgery.
- **Smokey And The Battery**—Peel-out power for electric police cars.

Editor: Abe Danc
Assistant Editor: Greg Pope
Contributors: Philip Chien, Mike Filion,
Will Swager

TECH UPDATE

News Of Tomorrow's Technology Today

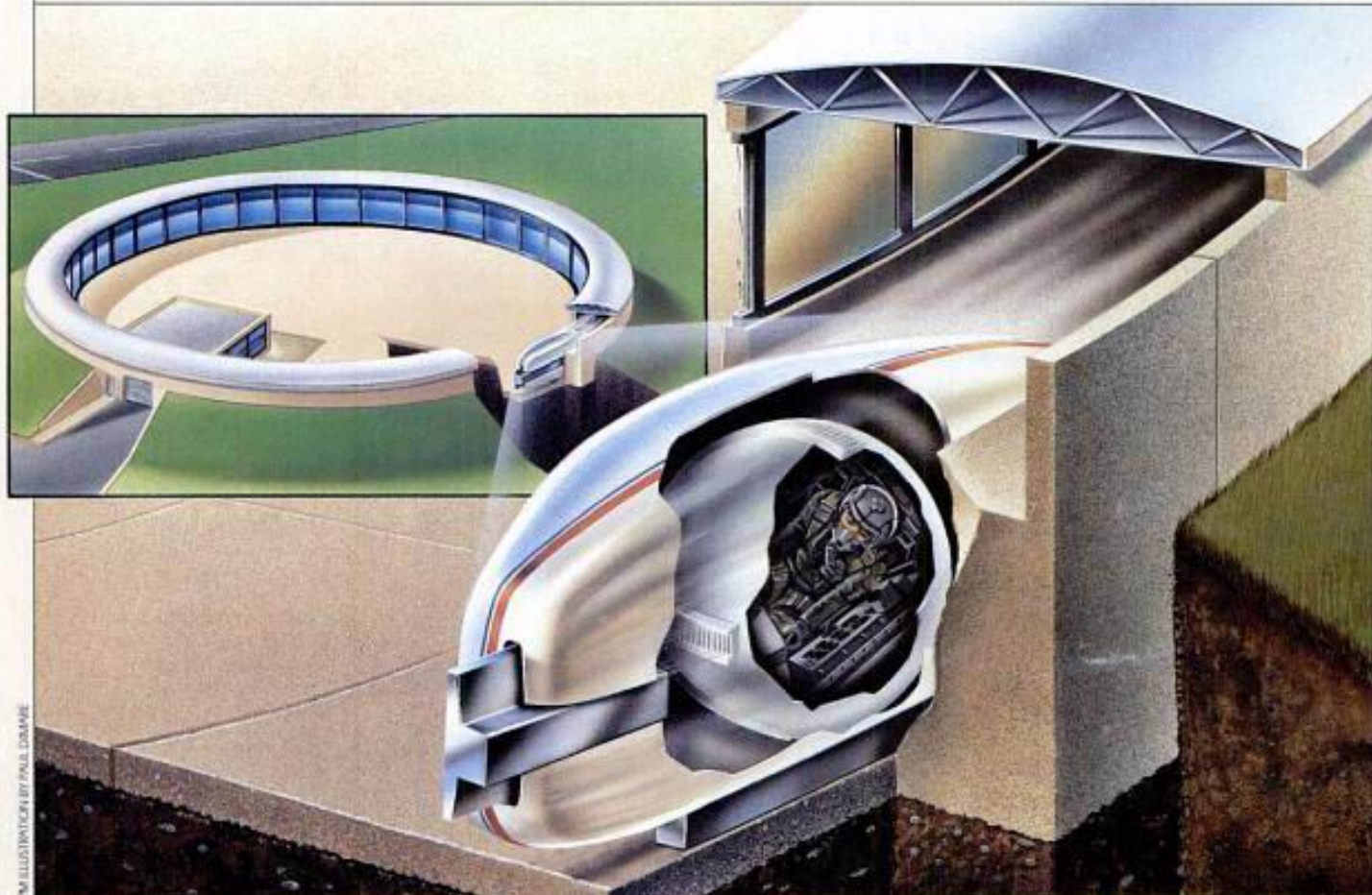


ILLUSTRATION BY PAUL DUNN

Super Centrifuge To Jump-Start Future Jet Jocks

BROOKS AFB, TX—The uncanny agility of emerging fighter jets presents a quandary for the Air Force. How can the service prepare pilots to handle the complex g-forces wrought by supermaneuverable aircraft like the F-22 and its successors?

One answer may be a proposed flight simulator that makes those old training centrifuges seem like merry-go-rounds.

At the Air Force's Armstrong Laboratory, engineers have outlined an electromagnetic vehicle that would whip around a ring of track roughly 600 ft. in diameter. Speeds would reach between 275 and 300 mph. The track could accommodate dif-

ferent vehicles, some even simulating spacecraft.

Inside, a sphere containing the trainee would spin freely on any axis—or several axes at once. The rotation would be driven by a proprietary traction mechanism that features arrays of wheels or ball bearings on the sphere's outer face.

Dubbed the Combined Acceleration Flight Simulator, or CAFS, the facility would depend on lightning-fast computers to synchronize motion with visuals. Flat or slightly curved electrochromic displays would line the inner face of the sphere.

Editor: Abe Dane
Assistant Editor: Greg Pope
Contributors: Lisa Busch, Mike Fillon,
Ed Jacobs, Herb Shuldriner

Currently at the preliminary concept stage, CAFS has not received further funding from the Pentagon.

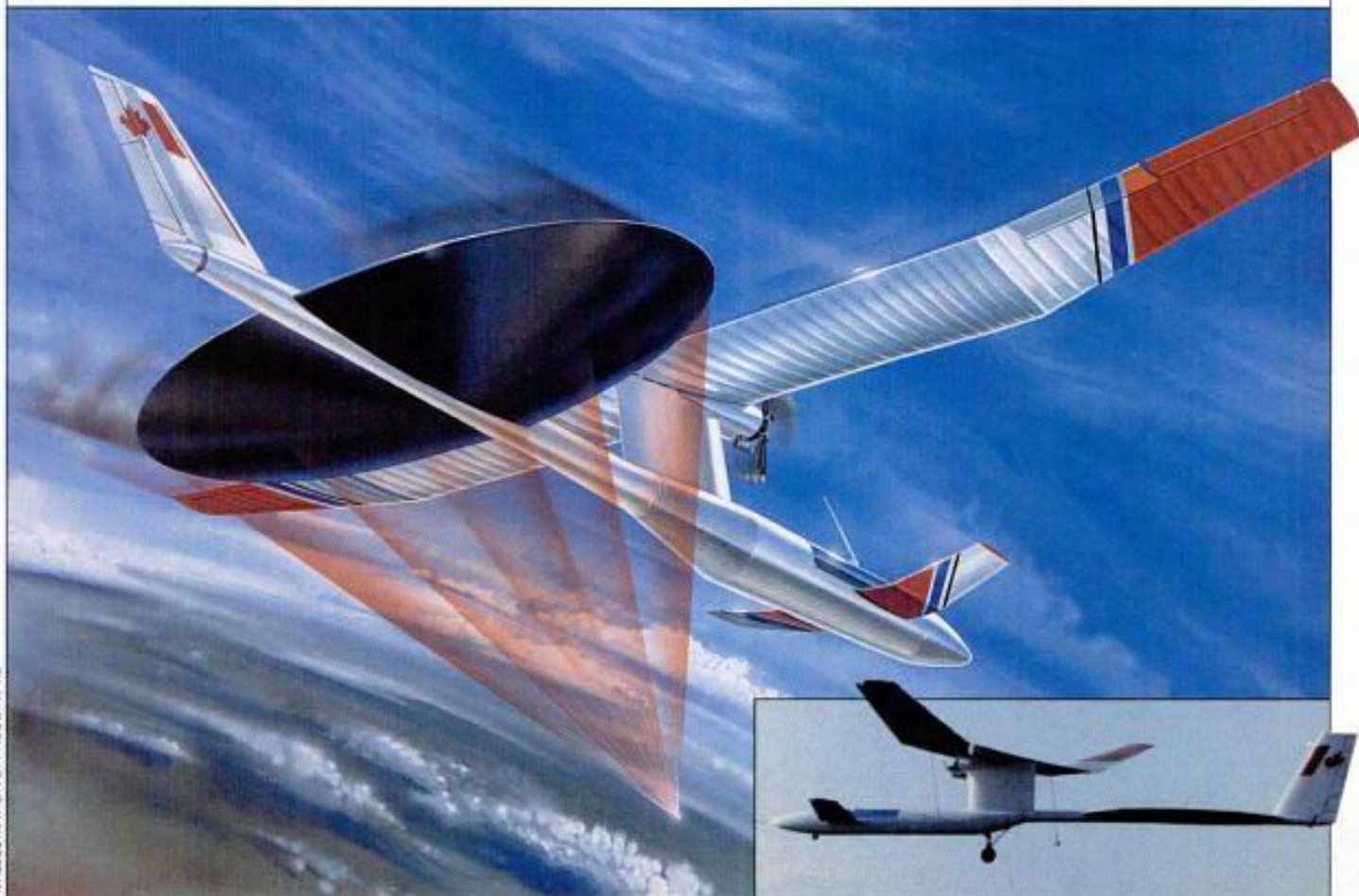
Catching g's from multiple angles, a pilot trainee gets supermaneuverable in CAFS simulator.

Highlights This Month

- **If Fish Could Talk**—Edible beepers tag deep-sea denizens.
- **One-Man Train**—Personal rapid transit comes of age.
- **Skydiving Tanks**—Army's future air-droppable armor.
- **World's Biggest Water Balloon**—The latest scheme to export Alaskan water.
- **Mechanical Milkmaid**—Robots invade the dairy parlor.
- **Traveling Wheels**—Japanese car folds into a suitcase.

TECH UPDATE

News Of Tomorrow's Technology Today



PM ILLUSTRATION BY PAUL DIMARE

Powerbeamed Drone Aims For The Stratosphere

BETHESDA, MARYLAND — Powered by a microwave beam, a small unmanned vehicle could hang in the air for months. But the concept has hung on the drawing board for years, because microwave powerbeaming systems have stayed big and costly.

Now things are changing. By jumping to a higher frequency, researchers feel they've vaulted the last obstacle to practical powerbeaming. A company called Endosat, Inc., has proposed a drone to fly at 80,000 ft., driven from a ground dish only 60 ft. across.

Key to the system: a Ka-band rectifying antenna, or rectenna, developed by

ARCO Power Technologies. The device converts a 35-GHz energy beam into DC current. Previous efforts in powerbeaming have used the S-band at 2.45 GHz, forcing either low-altitude operation or a prohibitively large dish to get enough power density on the rectenna.

Cut as conformal panels, the rectenna would attach to a disc on an airframe built for use with an earlier microwave system. Toronto-based Aeronautical Design, Inc., has already flown the vehicle with an internal-combustion engine.

Endosat is hoping to turn

the plane loose in the stratosphere, where it could carry instruments for atmospheric research.

Endosat drone, its rectifying antenna converting microwave beam into DC current, patrols the stratosphere.

Highlights This Month

- **Nuclear Blastoff**—Air Force unwraps secret atomic-rocket research.
- **Big Mouth**—Giant Airbus will outswallow Super Guppy.
- **Wet Suit**—Water-filled flightsuit fights g-forces.
- **Son Of Eggbeater**—Intermeshing rotors fly again.
- **Muscle Boat**—Pedal-powered hydrofoil shatters records.
- **Six-Legged Farmer**—Walking robot to tend crops.

Editor: Abe Danc
Assistant Editor: Greg Pope
Contributors: Philip Chien, Mike Fillon

TECHNOLOGY



An international quintet of spaceplane concepts now vies to provide the first cheap, reliable way into orbit. From top: Japan's SSTO, France's Star-H, America's X-30, Germany's Sanger and Britain's HOTOL, boosted by the Russian An-225.



SPACE RACE 2000

It's America versus the world in a high-stakes contest to launch an aircraft from runway to orbit and back.

BY GREGORY T. POPE; PM Illustration by Paul Dimare

● Fast-forward to the year 2000. The setting: Edwards Air Force Base, where a blue-and-white plane shaped like a blunt pencil point gathers momentum and takes off. The initial rocket blast gives way to the roar of ram-jets, soon drowned in a fusillade of sonic booms. Now out of eyeshot, the plane builds speed and noses for the stratosphere. An unearthly scream emerges, as ram-jets transition to supersonic combustion and propel the plane past Mach 8. Still the craft gains altitude and impossible velocity. Finally, the skimpy air can no longer satisfy the jets, and the rocket reignites to kick the vehicle into orbit.

This is the vision: routine American access to space from a runway, embodied in the X-30, the National Aero-Space Plane (NASP). But there can be no monop-

oly on such a dream. Flip the calendar ahead a few years and shift the scene to Germany. There, a black fang of a plane is slashing into the air from a refurbished Deutsche Aerospace runway in Manching, north of Munich. Accelerating headlong over Europe and the Atlantic, the plane climbs in a supersonic gallop until it reaches Mach 6.6. Then a smaller vehicle, carrying two astronauts, leaps from its back, fires a rocket engine and blasts into the heavens.

Jump ahead another decade, and aircraft are hopping from runway to space in Japan and France, perhaps even the former Soviet Union. That's because today, across the world, engineers are wrestling with the challenges of the aerospace plane, aiming to build vehicles that will blur the line between flight and orbit. Their en-

SPACE RACE 2000

deavors are spurring international aerospace competition to a new and hypersonic tempo.

The boldest of the schemes is NASP, jointly under study by the Air Force and NASA. If construction gets the green light in September 1993, twin X-30 test aircraft would first fly in 1997 and take a shot at single-stage-to-orbit flight in 1999. Technology hurdles, still formidable, may slow down that aggressive timetable. But so far, progress in materials and propulsion for the Mach-25 vehicle has been on schedule.

Next on the runway is Sanger, Germany's 2-stage-to-orbit system. Technically less ambitious than NASP, Sanger could leapfrog the X-30s by executing real missions. The American aircraft, by contrast, will be strictly experimental, paving the way for mission-oriented "NASP-derived vehicles."

Behind these frontrunners are Japanese and French craft that will move from concept to reality in the 21st century, presumably after those nations have proven their proposed minishuttles, *Hope* and *Hermes*. Meanwhile, British and Russian engineers hold a wild card: a joint proposal to launch an unmanned spaceplane called HOTOL from the back of an Antonov An-225, the mammoth Russian cargo jet.

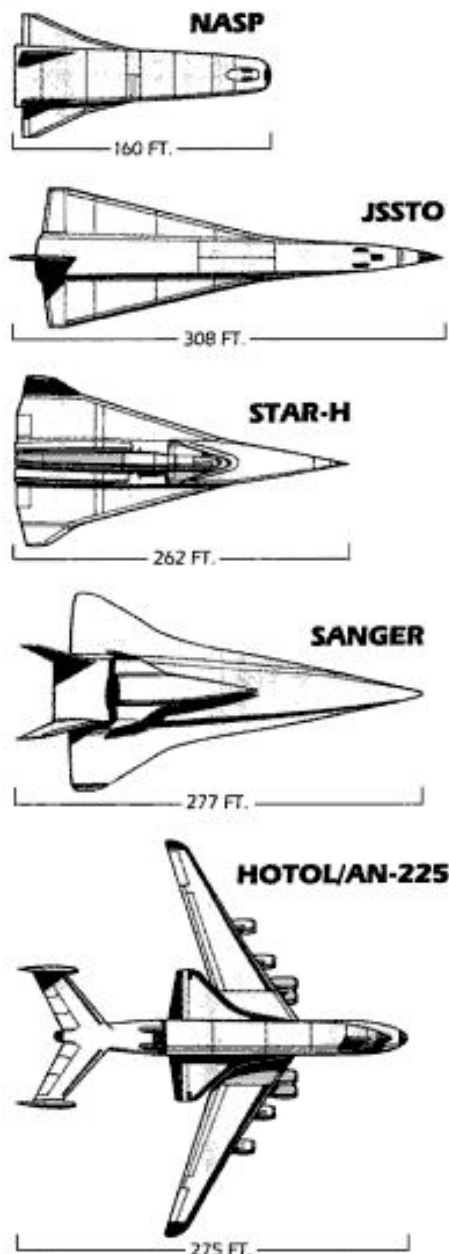
NASP in the grasp

In the face of such competition, say NASP contractors, the brazen audacity of the X-30's performance goals will give the American aerospace industry a needed technological leg up—if those goals can be met. With that motivation, an unprecedented five prime contractors comprise the NASP National Program Office, based near Air Force Plant No. 42 in Palmdale, California.

Consider these demands: The X-30 will be as long as a Boeing 767, weighing dry only 100,000 pounds. Yet it must take off laden with 250,000 pounds of slush hydrogen to get into orbit. At the same time, its nose must withstand 5000° F temperatures, its leading edges 3000° F, while air temperatures inside the scramjet combustion chamber will reach 12,000° F. The question: What do you build the plane out of?

"That's where we've made such remarkable progress," says Dr. Robert Barthelemy, director of the Air Force/NASA joint-program office, which oversees the contractor work. The X-30 will be a crazy-quilt of composites and alloys that were impossible hybrids just five years ago.

Graphite-copper has emerged as a



likely candidate for combustion-chamber walls and leading edges, where hydrogen will circulate through built-in capillaries to cool things down. Titanium aluminide, laced with ceramic strands, will be used for fuselage panels and fuel tanks. Already, contractors are flattening and sculpting large sheets of this brittle material.

But Barthelemy admits that propulsion remains the biggest worry. Rocket combustion, probably oxidized with a built-in liquid-air compressor, will boost the plane from a standstill to Mach 3. NASP engineers are now convinced that, between Mach 1 and 3, external fuel combustion is necessary behind the rocket engine to keep the exhaust plume pushing against the base of the tail.

Above Mach 3, air compressed by the plane's forebody will squirt through each of six ramjet/scramjets, reaching supersonic speeds. Injection

and ignition of hydrogen fuel must be timed perfectly to avoid triggering shock waves that would choke off airflow. Combustion mustn't fall short of peak expectations—95% efficiency—or else the plane will run out of fuel before reaching Mach 18, when the rocket takes over for orbital insertion.

The NASP scramjet, the "flying stovepipe" that must perform so flawlessly, can't be ground-tested throughout its grueling flight envelope. "When we push the envelope of the plane, we'll be pushing the envelope of the engine," says Barthelemy. "That's the difference between this X-plane and previous ones." So far, scaled-down engines have responded favorably in wind tunnels up to Mach 8. Ground tests at higher speeds must wait until a decision is made to complete RHYFL, a half-built shock-tunnel facility engineered by Rocketdyne. RHYFL would unleash Mach-24 blasts—but only for a fraction of a second.

Doing the 2-step

Meanwhile, in Germany, researchers at Messerschmidt-Bölkow-Blohm (MBB) have it a little easier. The Mach-6.8 Sanger first-stage will fly on turbo-ramjets, fed kerosene jet fuel while the turbines are humming, then liquid hydrogen in ramjet mode. Although the engines must shift smoothly from turbojet to ramjet operation, the plane won't move fast enough to require scramjets.

Temperatures on the nose and leading edges will stay cool enough that the plane can be built of conventional titanium padded with carbon-carbon at the hot spots. "We won't need exotic materials," predicts Dietrich Koelle, director of advanced studies and scenarios at MBB in Munich.

One thing the Germans will need is some tricky engineering to manage second-stage separation. Perched on Sanger's back, the winged flyback orbiter will come in both manned and robotic versions. At 22 miles off the ground, Sanger will first nose heavenward at a 6° angle. Then the orbiter itself must rear up at an 18° angle to the first-stage carrier before disengaging and igniting its rocket. Already cruising at its top speed, Sanger must have extra thrust available to counter the increased drag from the maneuver, Koelle says.

The Germans, purse strings clenched by the costs of unification, have already roped in Sweden and Italy as research partners on Sanger. Construction of a demonstrator aircraft called Hytex has been put off for five years. As an alternative, the Germans are seeking to borrow a NASA



Sanger takes two steps to orbit.

SR-71 Blackbird to air-launch an unmanned testbed for their turbo-ramjet engine. (NASP engineers may get first dibs, however, to verify external combustion's effectiveness.) But still unanswered is how quickly the European Space Agency, already tied to its *Hermes* minishuttle and its mammoth booster *Ariane 5*, will assume funding of full-scale Sanger development.

"*Hermes* is a good step, but not the final answer to keeping launch costs down," argues Koelle. One advantage Sanger will have over *Hermes*, he says, is the ability to hop into space from any airport in Europe, which bars unmanned rocket launches from the Continent.

But researchers at France's Aerospatiale and Dassault Aviation, prime contractors on *Hermes*, are outlining their own hypersonic concepts. Under a research effort called STS 2000, Aerospatiale has tailored a Concorde-like single-stage spaceplane and a 2-stage system wedding a Mach-13 scramjet with a winged flyback rocket. Meanwhile, Dassault's STAR-H is closer to Sanger. The STAR-H scenario stars a Mach-7 plane that would piggyback an expendable *Ariane-5* second stage tipped with a *Hermes*-derived reusable orbiter.

By lifting technology from *Hermes* and *Ariane 5*, French engineers can concentrate on developing the air-breathing first stage, says Michel Rigault, technical director of space transportation systems studies at Dassault. The French government has targeted the scramjet for a major research push, with four aerospace firms planning to throw in together à la NASP.

HOTOL recall

Two countries that have already thrown in together are the unlikely duo of Great Britain and Russia. In the mid-1980s, British Aerospace and Rolls-Royce developed a concept known as HOTOL (Horizontal Take-Off and Landing), an unmanned re-

usable single-stage-to-orbit vehicle driven by a combined airbreathing/rocket powerplant. The program stagnated, however, when the British government ceased funding.

But since 1990, British Aerospace and Russia's Antonov Design Bureau have mulled the feasibility of launching a simplified HOTOL at 29,000 ft. from the back of Antonov's An-225 heavy-lift cargo jet, the world's biggest plane.

The new HOTOL incarnation could get by on a conventional rocket engine of Russian pedigree. Meanwhile, the An-225, already designed to carry payloads on its back, would still require an extra pair of engines and some heat shielding. Allowing the



NASP does it in one step.

Russian jet to haul HOTOL through much of the atmosphere would free up several tons of extra payload capacity aboard the spacecraft.

Recent wind-tunnel tests indicate that separation would go off without a hitch. "My impression is that the Russians and British are getting serious," says Barthelemy. "They might try to pull off a launch in two years, and that would scoop everyone."

Meanwhile, Japan, nurturing its own fledgling aerospace industry, isn't about to be left out. Japanese engineers have recently aired a bewildering plethora of proposals, but their ultimate aim is to fly a plane into space in the 21st century. The Japanese Single-Stage-To-Orbit, or JSSTO, would couple four liquid-air-compression engines with six scramjets.

And they're off

The flurry of research activity—and promises of generous government funding—suggest that Japan is jockeying hard for a place on the hypersonic racetrack. "The Japanese always talk an interesting story on what they might or could do," says Barthelemy, "but we all know they can move out when they want to. They're looking at this commercially, because they'd like to be in the high-speed people-moving business."

But the short-term challenge to American aerospace supremacy, Barthelemy believes, comes not from Japan but from Germany. "You bet we're in a race," he says. "The Germans are focused, and they have a strong commitment."

What spoils go to the winner? For Germany, it's a chance to play a leading role in Europe's emerging space program, providing a flexible counterpoint to *Ariane 5* and *Hermes*. For Japan, it's another opportunity to parlay high technology into a thriving business.

For the U.S., the stakes are higher. NASP research may give the Air Force a spyplane or a strategic bomber that can get to its target faster than a ballistic missile. But for NASA, NASP represents the likely follow-on to a Shuttle system slipping into disfavor. Shuttles spend a minimum of 30 days on the ground between missions. Launch costs exceed \$2000 per pound of payload, and 15,000 federal employees must work to maintain and operate the spacecraft.

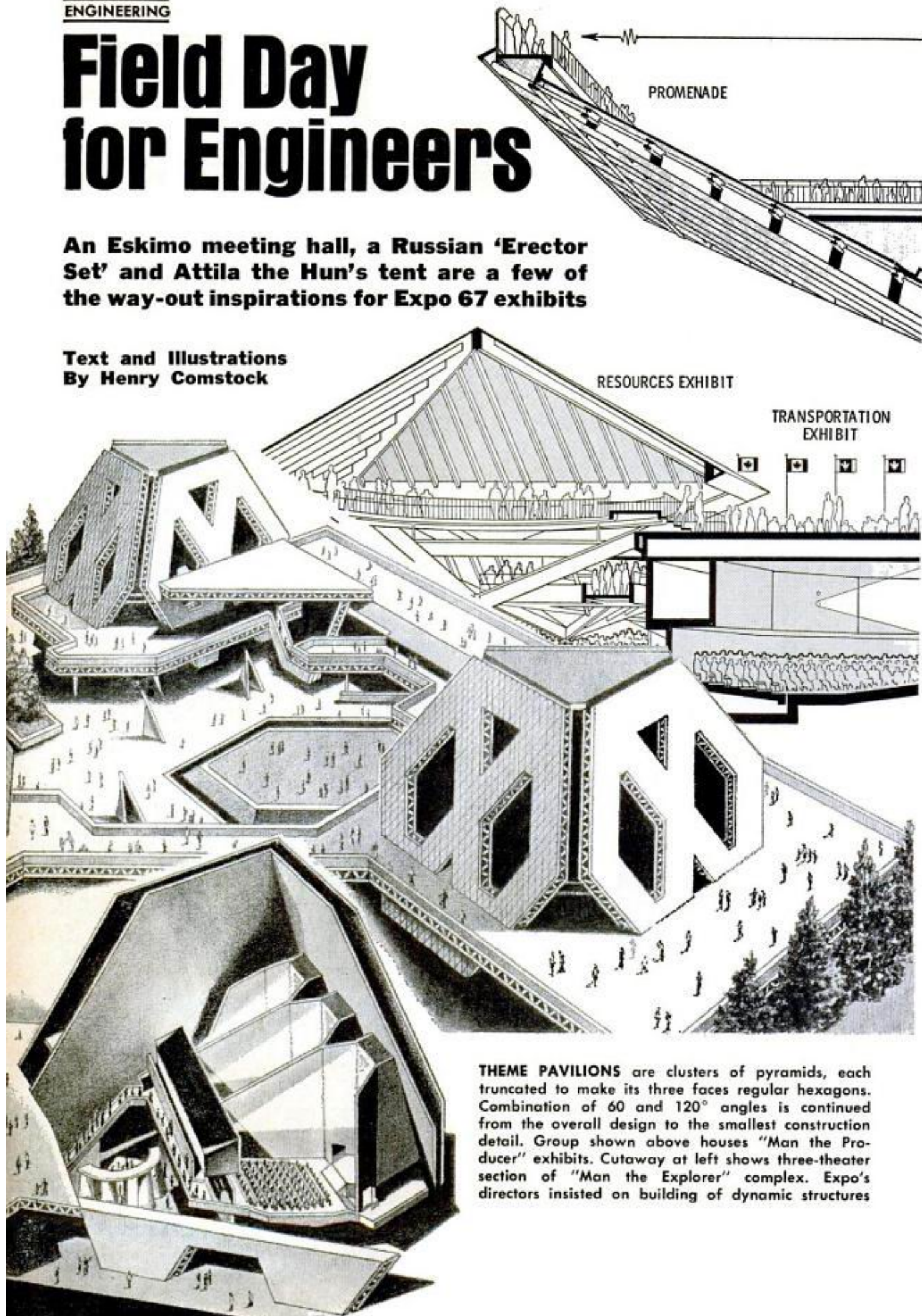
In contrast, a NASP-type vehicle could, according to Barthelemy, return to space 72 hours after touchdown, require between \$50 and \$400 per pound of payload, and tie up only 100 workers. In addition, he notes, the temperamental Shuttles will be over 25 years old by the time a NASP-derived craft gets off the ground.

Whatever the mission for a NASP-derived craft, it probably won't be the only flying machine to slip the bonds of gravity and venture into orbit. Space Race 2000 is on. **PM**

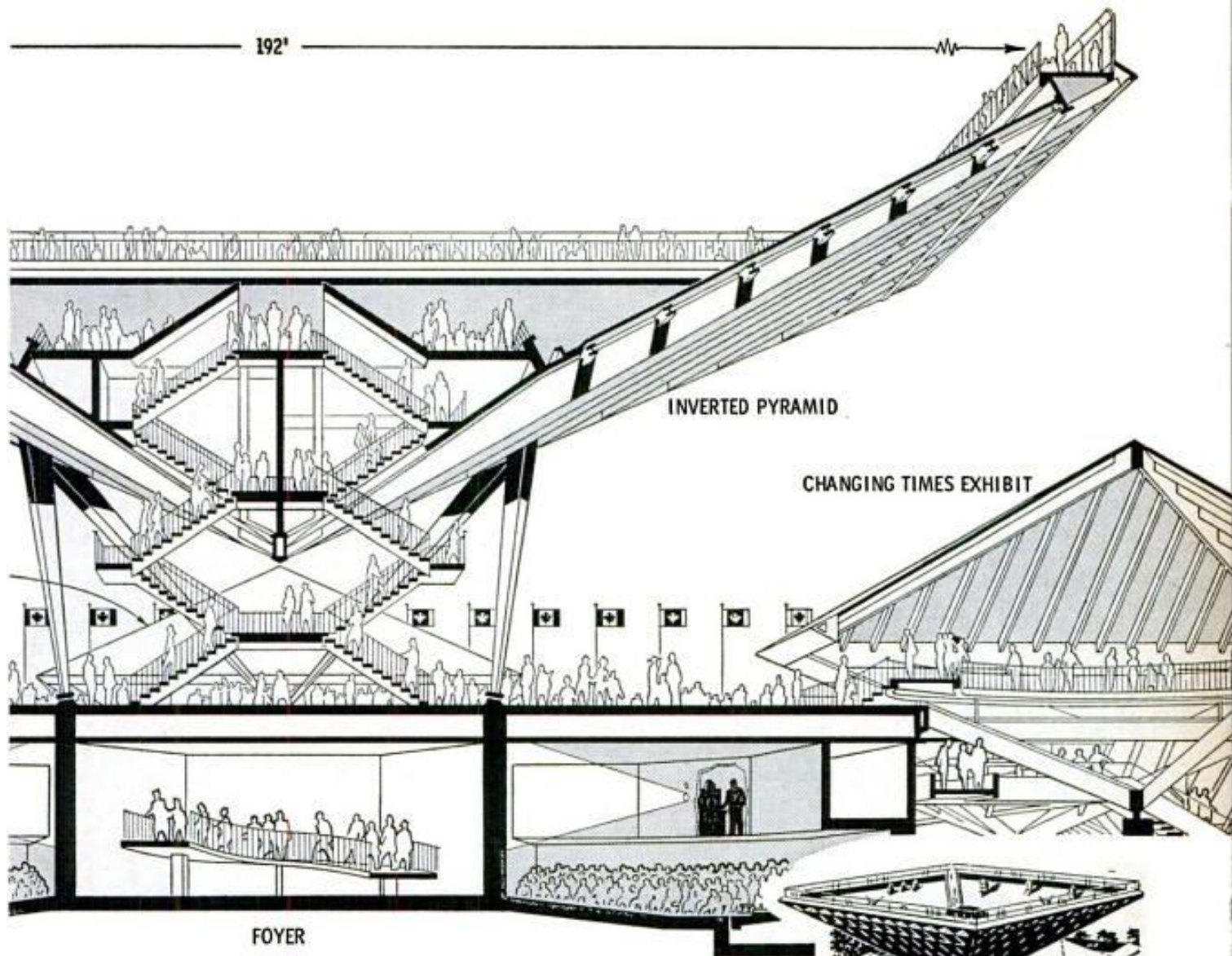
Field Day for Engineers

An Eskimo meeting hall, a Russian 'Erector Set' and Attila the Hun's tent are a few of the way-out inspirations for Expo 67 exhibits

Text and Illustrations
By Henry Comstock



THEME PAVILIONS are clusters of pyramids, each truncated to make its three faces regular hexagons. Combination of 60 and 120° angles is continued from the overall design to the smallest construction detail. Group shown above houses "Man the Producer" exhibits. Cutaway at left shows three-theater section of "Man the Explorer" complex. Expo's directors insisted on building of dynamic structures



CANADIAN PAVILION complex is topped by 100-foot inverted pyramid called *Katimavik*, Eskimo for "meeting place." Below four supporting columns, a slowly rotating theater will offer 950 seated spectators a filmed history of Canada's growth. Exhibits in three connected pyramids will feature Canadian resources, transportation and changing times. From the lip of the 102-foot *Katimavik*, promenades will view displays on the vinyl-skinned structure and, outside, panoramas of the fairgrounds, the St. Lawrence River and Montreal. The fair has been built on largely man-made islands in the river



EXPO 67 THE ONLY spectacular you'll miss at Canada's newly opened Expo 67 is the construction spree which produced its 1000 acres of eye-popping pavilions.

This hardhat's field day began when our northern neighbor invited the world to set up shop at its Centennial Exhibit. More than 70 nations sent architects and engineers to Montreal.

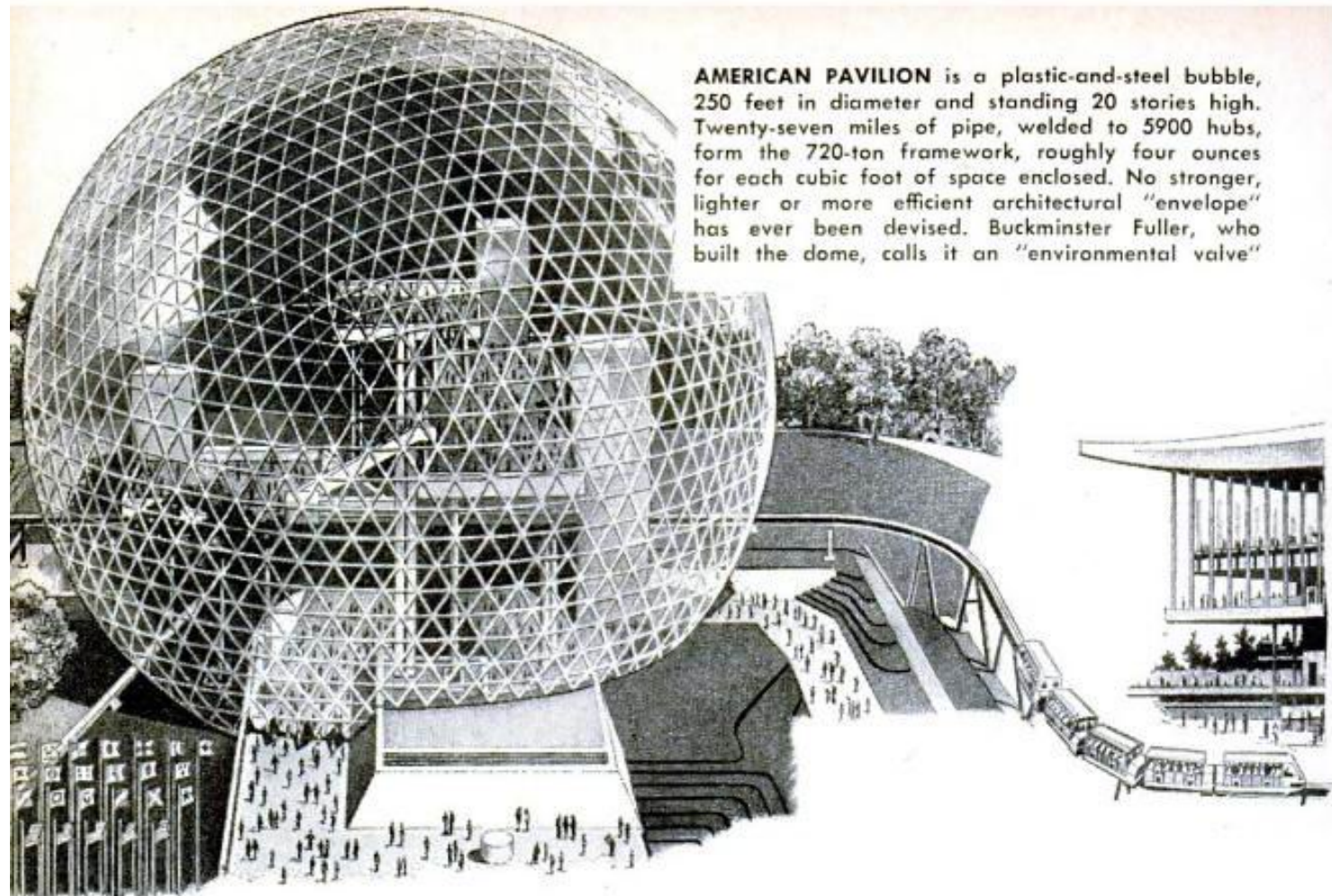
They were shown a handsome building site—an arm of the St. Lawrence waterfront and two adjacent islands. Seven-million cubic yards of fill had been plopped into the stream to extend the peninsula, form one of the "îles,"

and double the area of the other. Diked pockets marked locations for coming lagoons, Venetianlike canals and a marina.

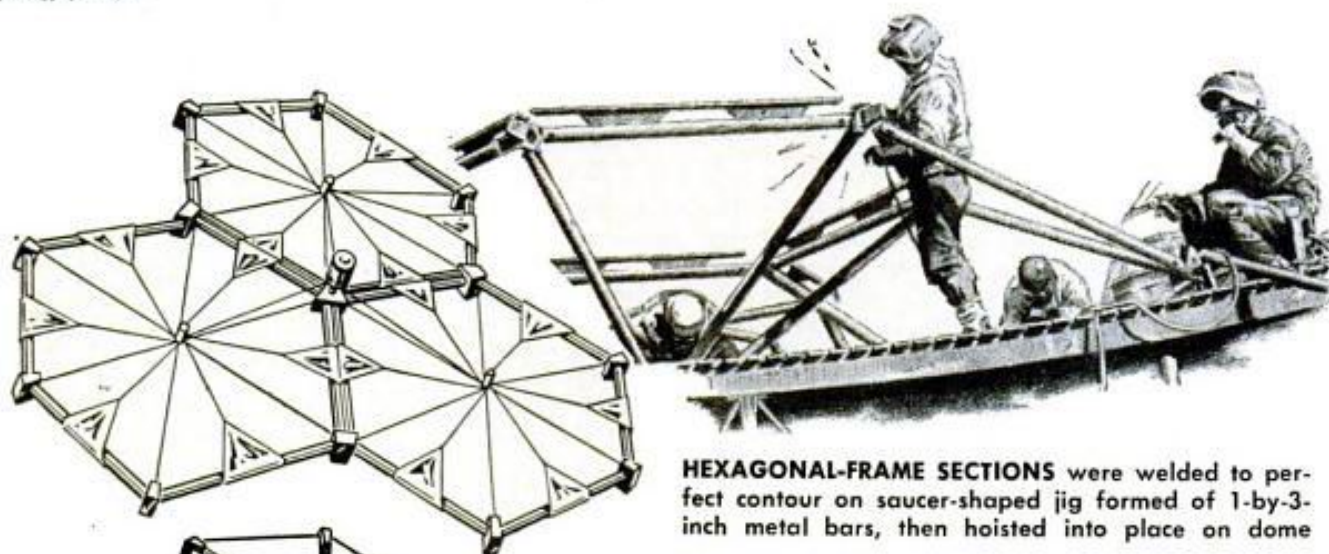
Expo 67's directors tactfully made it clear they wanted no static structures marring that setting. Instead, the pavilions should match the free-wheeling mood of the river itself.

This was all the T-square and slide-rule artists wanted to hear. Some of the steel, glass, plastic, plywood and concrete palaces they whipped up would turn a Martian pink with envy. Others were only awesome, thought-provoking or good for a laugh.

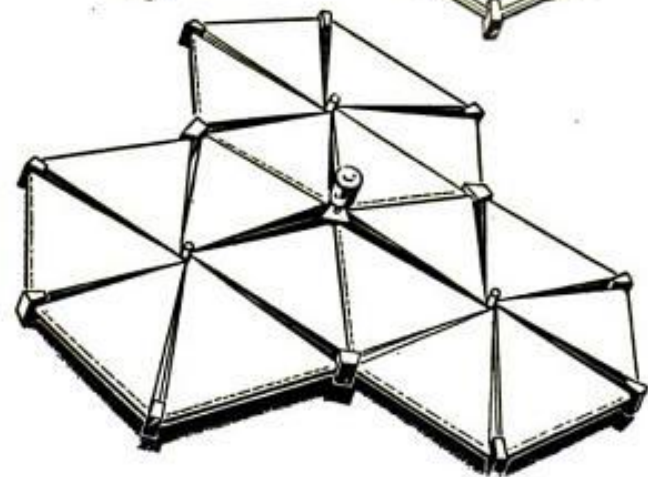
No one can tell you which are which;



AMERICAN PAVILION is a plastic-and-steel bubble, 250 feet in diameter and standing 20 stories high. Twenty-seven miles of pipe, welded to 5900 hubs, form the 720-ton framework, roughly four ounces for each cubic foot of space enclosed. No stronger, lighter or more efficient architectural "envelope" has ever been devised. Buckminster Fuller, who built the dome, calls it an "environmental valve"



HEXAGONAL-FRAME SECTIONS were welded to perfect contour on saucer-shaped jig formed of 1-by-3-inch metal bars, then hoisted into place on dome



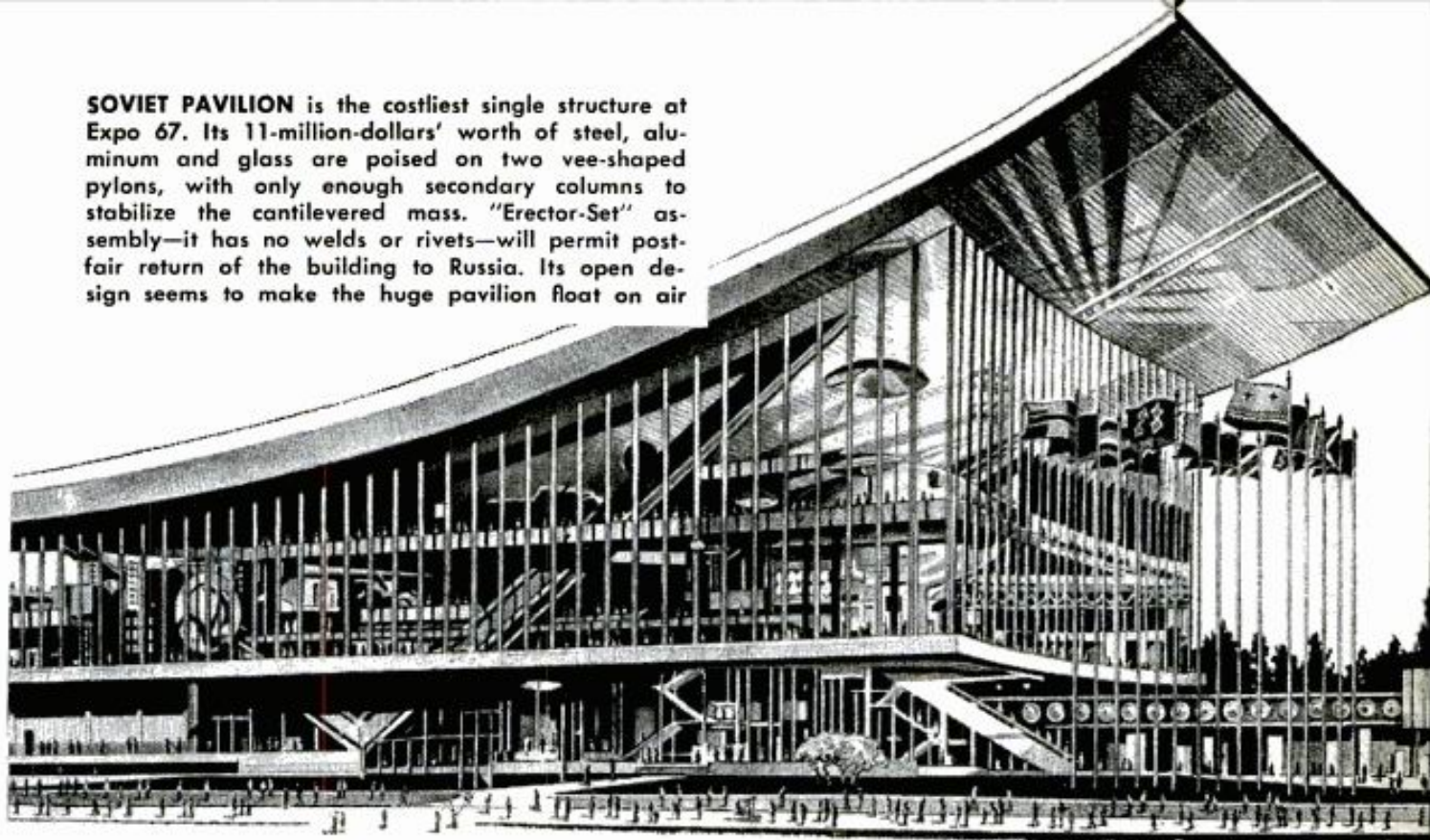
THERMOSTAT-TRIGGERED MOTORS draw heat-retracting shades across acrylic-glazed hexagons when sunlight is intense, governing temperatures inside huge geodesic dome—part of environmental control

it's a decision you have to make for yourself. But here are some random notes that may suggest why Expo 67's attendance counters are expected to click 30 million times before the wrecking cranes move in next November:

- **Canada's Katimavik.** An inverted pyramid nine stories tall, symbolizing Canada's spreading development. Filled with music as well as exhibits, it may kindle wistful gleams in the eyes of audiophiles, unhappy with 12-inch woofers.

Within the base, a carousel theater,

SOVIET PAVILION is the costliest single structure at Expo 67. Its 11-million-dollars' worth of steel, aluminum and glass are poised on two vee-shaped pylons, with only enough secondary columns to stabilize the cantilevered mass. "Erector-Set" assembly—it has no welds or rivets—will permit post-fair return of the building to Russia. Its open design seems to make the huge pavilion float on air

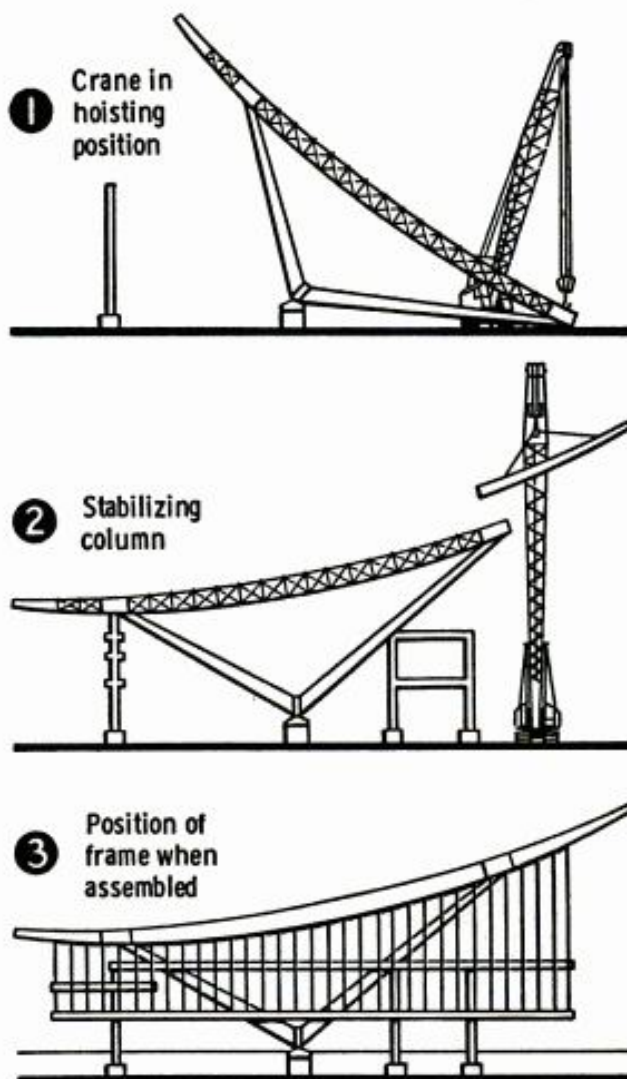


with five pie-shaped seating sections and a sixth for loading, will hitch audiences from one showing to another, revolving once each half hour.

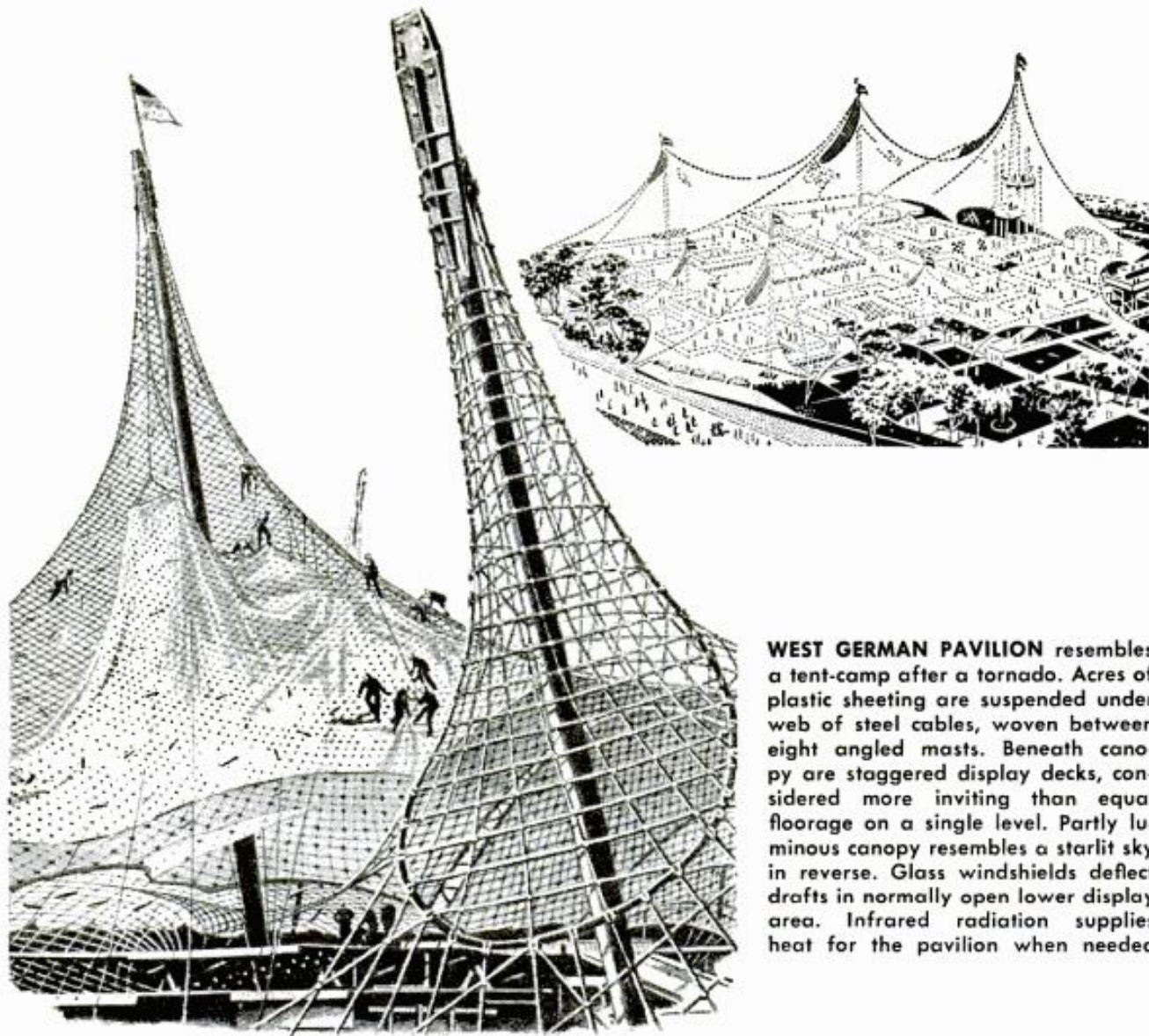
● **Uncle Sam's Big Bubble.** Seventy-year-old architect-engineer Buckminster Fuller has rolled out his largest geodesic dome yet. He describes it as "an environmental valve; the kind within which whole communities may some day enjoy a benign microcosm." This prototype literally breathes through a system of exhaust vents spotted among its 2000 acrylic "windows." The plastic is tinted to reduce glare and, for temperature control, retractable screens travel across the surface of the sphere, following the sun.

Inside, six-story-high exhibit decks are interlinked with bridges, elevators and escalators. One moving stairway has a 123-foot free span—world's longest.

● **Russia's Ambient Arena.** With its cantilever construction and 10,000 square yards of plate glass, this huge pavilion seems to float on air. But under its curved roof (big enough to hold 1000 automobiles) there's sufficient steel for a 30-story office building. While the architects were Russian, all of that metal, along with the aluminum



TWO 400-TON MAIN FRAMES were teetered to cantilevering position with the 120-ton tug of a long-boomed crawler crane. Oddly, the Russian pavilion was constructed by Italian engineers and field crews



WEST GERMAN PAVILION resembles a tent-camp after a tornado. Acres of plastic sheeting are suspended under web of steel cables, woven between eight angled masts. Beneath canopy are staggered display decks, considered more inviting than equal floorage on a single level. Partly luminous canopy resembles a starlit sky in reverse. Glass windshields deflect drafts in normally open lower display area. Infrared radiation supplies heat for the pavilion when needed

used for surfacing and trim, was prefabricated in Rome and Milan. Italian engineers and field crews erected it.

The chief attraction here is a simulated moon flight. With only 70 seats in the space capsule, waiting lines may be like those at a fogged-in airport.

- **West Germany's Tent City.** Externally a zany network of cables, with the ends of tilted masts piercing three acres of translucent fabric, this may suggest that some huge cranes were found on the grounds opening day, and not too successfully hidden with a tarp.

But inside, the effect is handsome. The partly luminous canopy, anchored to the unseen cables, looks like a starlit sky in reverse. In good weather, the lowest display area is kept open, with drafts controlled by windshields.

- **Transportation.** Sometimes sharing plazas with, and in one case passing completely through the U.S. pavilion,

three small monorail systems are practically a part of the exhibit's architecture. Each line is a closed loop, traveled by trains of the straddling, rather than suspended, type. Imported from Lausanne, Switzerland, and Munich, Germany, 32 of these "Minirailers" ramble over 46 collective miles. There are no operators; a station attendant simply pushes a starting button and the cars amble away at a leisurely seven mph. A computer keeps traffic spread out.

Automatic operation doesn't bother the passengers here, but on the standard-size, multiple-unit trains which whisk foot-weary fairgoers between the peninsula and the islands for free, high operating speeds had an unnerving effect upon riders when the equipment was first tested. So while he does nothing but open and close the doors, an authoritatively uniformed "motorman" now sits at the head of each flyer. ★★★

No Snorkel, No Scuba

ARTIFICIAL GILLS:

They'll Let You Breathe Like a Fish

Newest underwater breakthrough 'filters' oxygen from water

By WALLACE CLOUD

Illustration by Dale Gustafson

CAN MAN BREATHE like a fish? Why not? Talk to a few of the people who are working on the problem, and what once seemed incredible suddenly seems obvious: A diver doesn't have to carry air tanks—he can get oxygen from the water around him.

Like other science writers, I was a bit skeptical a few years ago when Commandant Jacques-Yves Cousteau, co-inventor of the aqualung, predicted divers would become "men-fish," *breathing water*. He claimed, also, that it would soon be possible to plug an "artificial gill" into man's bloodstream. Today, this is what's happening:

- Two American inventors have patented artificial gills that let a diver breathe into his lungs the oxygen that is dissolved in the water, and get rid of exhaled carbon dioxide by the same route.

- These gill systems promise to eliminate or minimize diving problems: the bends, nitrogen narcosis, oxygen poisoning. Conceivably divers will move up and down in the ocean as freely as fish, without decompression stops.

- Scientists now talk seriously of circulating the diver's bloodstream through a gill unit, bypassing the lungs. Two divers for an undersea-engineering firm have volunteered to undergo surgery necessary to implant such a device.

- The same kind of gill system can be used to supply fresh air in submarines and undersea stations.

When Cousteau, in 1962 predicted gills for men, he could not have known that one kind of gill had already been tested. The turning point came on Aug. 6 that year, when a Rutherford, N.J., research engineer named Waldemar A. Ayres and his wife went on a secret mission to Jones Beach, N. Y.

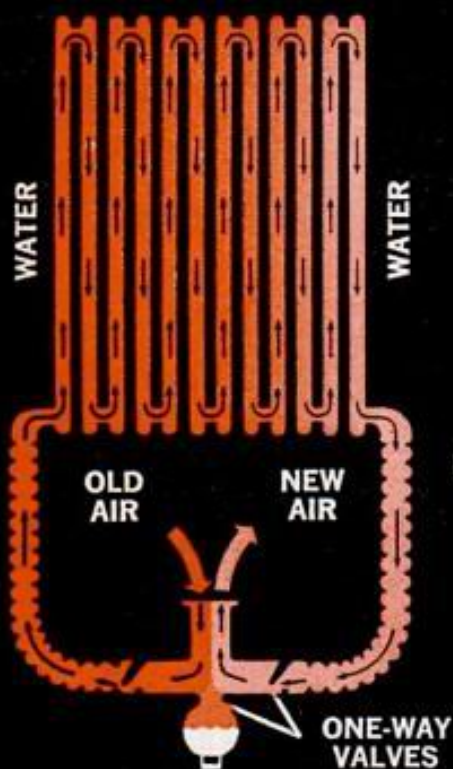
Ayres unrolled four foot-wide strips—actually flat plastic tubes, each 25 feet long—and carefully inspected them. (One side of each tube was made of fragile material.) He interconnected them with short lengths of garden hose and hooked up a scuba diver's mouthpiece. Valves at the mouthpiece were arranged so his exhaled breath would travel the entire combined length of the tubes, then be reinhaled.

He floated the tubes on the water, fragile side down. Then he sat down in the water, clamped his nostrils shut with a clip, put the mouthpiece in his mouth and proceeded to inhale and exhale through the apparatus for an hour and a half as it bobbed up and down on the waves. He stopped only when water leaking in made it hard to force his breath through the tubes.

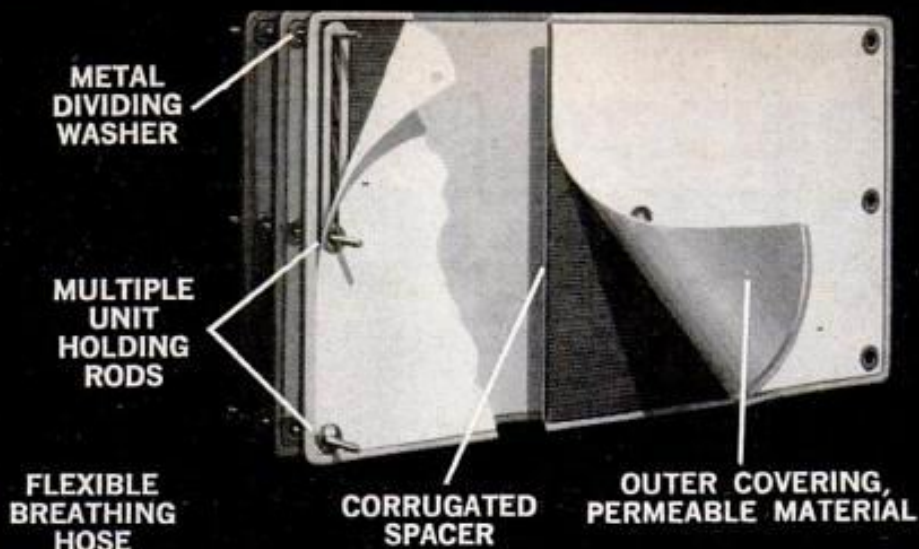
Wally Ayres thus became the first human to successfully breathe dissolved oxygen from the water like a fish.

How could he be sure? The top side of each tube was made of tough, airtight upholstery vinyl. No oxygen could get in from that side. But the side immersed in water was a spongy polyethylene

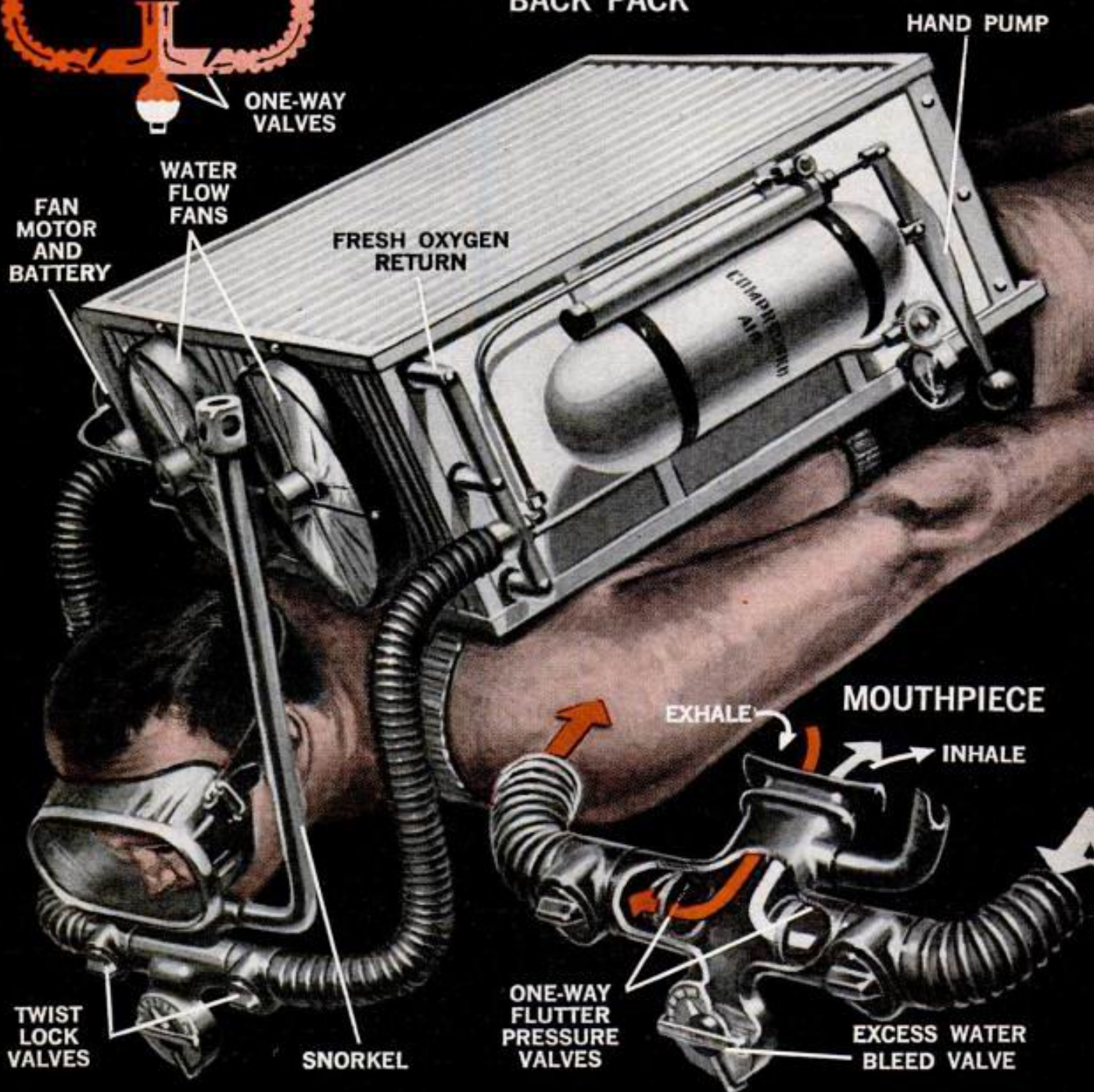
OXYGEN-CO₂ EXCHANGE CYCLE



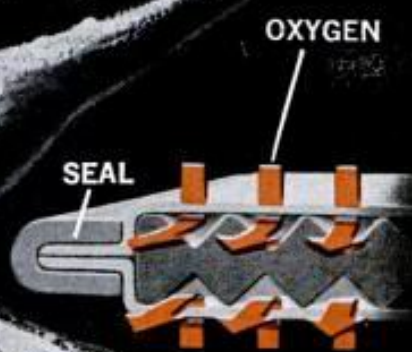
GILL MEMBRANE



BACK PACK



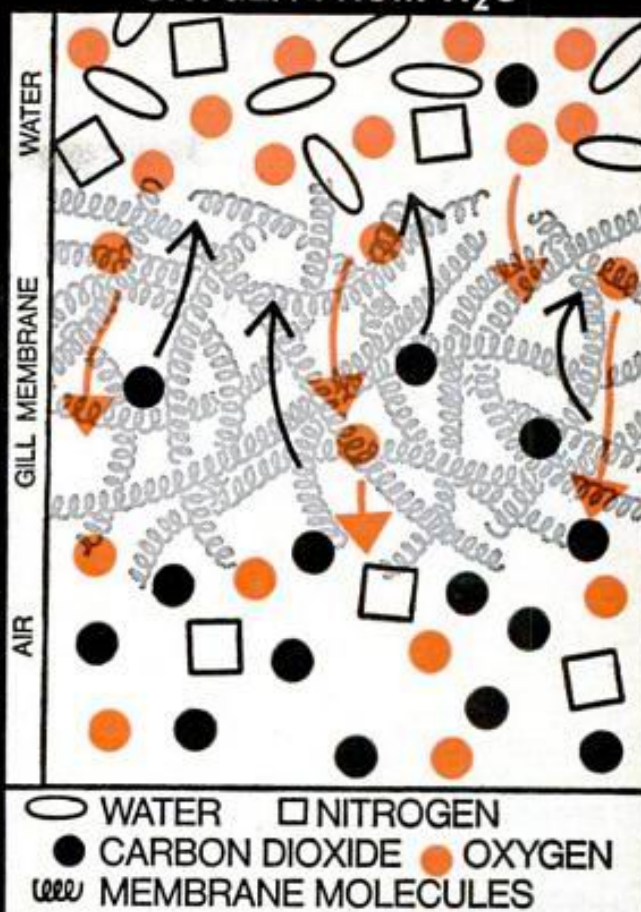
CROSS SECTION OF GILL



TWO-WAY STREET: Molecules of gas can go in either direction between larger molecules of the membrane; which way they go depends on "partial pressure"—a larger supply of molecules on one side of the membrane.

Oxygen molecules, more numerous in water than in diver's exhaled air, diffuse into gill through the membrane. There is a larger "population" of carbon dioxide molecules inside the gill than there is dissolved in water, so CO₂ travels out.

HOW GILL SEPARATES OXYGEN FROM H₂O



material—containing millions of microscopic pores—designed originally for baby pants. Through this membrane, his breath was in contact with the water; oxygen diffused from the water into the air in the plastic tubes, and carbon dioxide diffused from the air into the water.

If it hadn't worked, Ayres would have experienced the symptoms of anoxia and carbon dioxide excess: flushed face, difficulty in breathing. Or he could have passed out in minutes.

The next day Ayres repeated the performance while a friend observed, took pictures, and recorded the time. The information was then incorporated into an affidavit. Ayres was in the middle of a 10-year struggle to get the U.S. Patent Office to recognize his invention.

That's the way Ayres told me the story, which he had kept secret during the touch-and-go process of getting the basic patent (No. 3,228,394) on all underwater breathing systems using the gill principle.

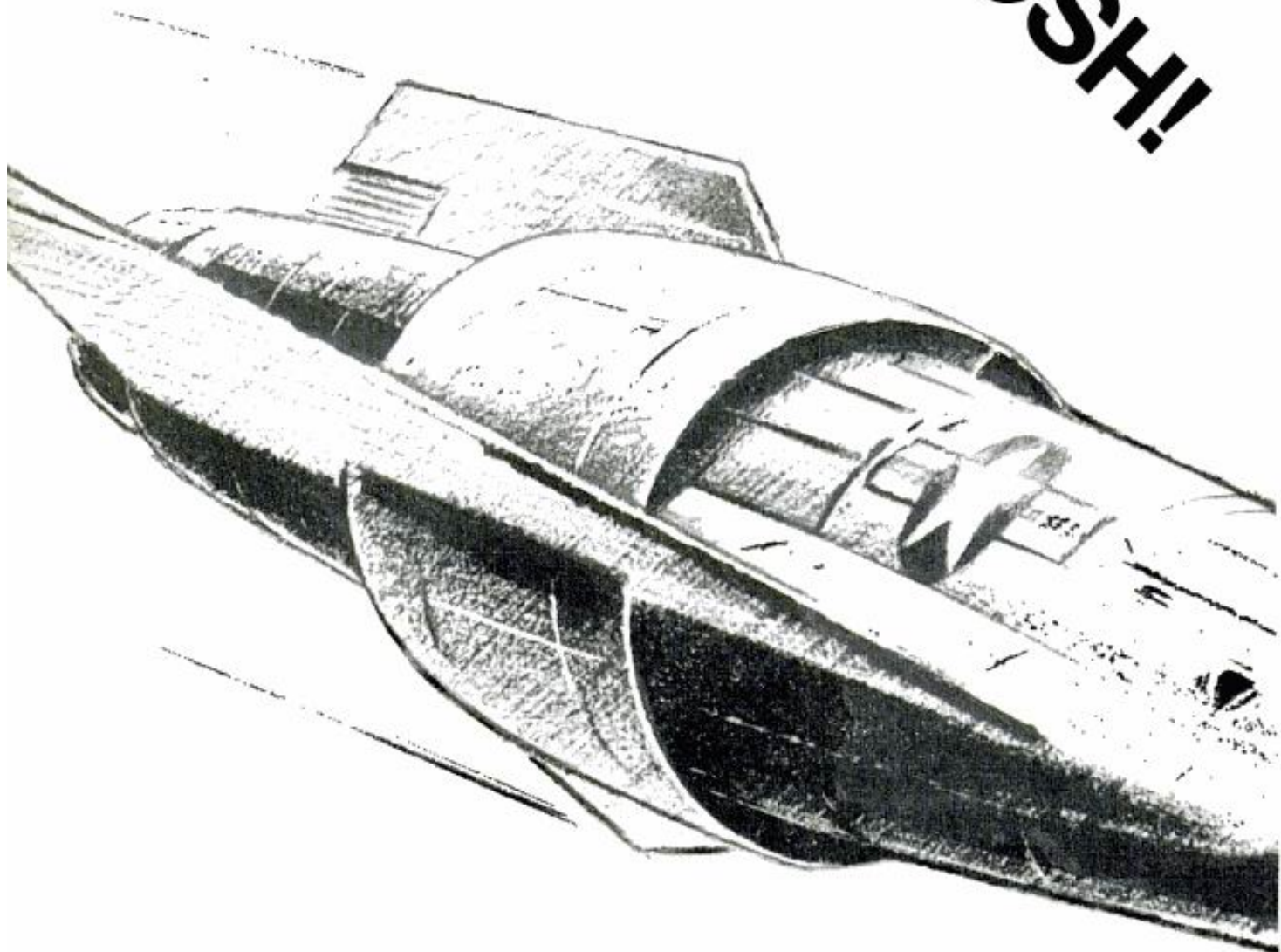
He had conceived the idea in 1955, while scuba diving in the Bahamas. After all, he reasoned, there isn't a vast difference between a fish's gill and the human lung. In both cases blood moves past one side of a membrane; on the other side is the oxygen-bearing medium—air or water.

Both gills and lungs work because of "partial pressure." This means that in a mixture of gases, the pressure of each gas is a fraction of the total pressure of the mixture. That fraction—the partial pressure of a single gas—is proportional to the percentage of the gas in the mixture.

For example: Air consists of about 78 percent nitrogen, 21 percent oxygen and small amounts of other gases including carbon dioxide. Atmospheric pressure at sea level is 14.7 pounds per square inch, so the partial pressure of oxygen in the air is 21 percent of 14.7 p.s.i.

In water exposed to the air, the gases are dissolved in the same proportions;

WHOOOSH!



The flying

Supersonic transport? Forget it! They're working on a Scramjet that will fly you 8000 mph

By KEVIN V. BROWN

WANT TO GO FOR A RIDE? I mean a *real* ride! You've been in a big jet? That's like 600 mph tops. Nothing. You hope to ride in a supersonic transport? They'll do well to make 2000 mph. Still nothing.

Like the man said, you ain't seen nothing yet. Climb aboard the Scramjet. We're going for a *real* ride!

The cockpit looks as if it's all throttles. I count nine of them. The pilot uses just one for takeoff. Halfway down the runway, accelerating rapidly, he rolls the nose back and we start climbing at an angle of nearly 45°. Still climbing, still accelerating, we watch the mach gauge jump from .95 to 1.1. We're supersonic at 30,000 feet and still going up.

At 70,000 feet, doing about Mach 2.5, the pilot kicks in the other eight engines. Now we really take off! Whoosh! The pilot levels off at 100,000 feet and the mach gauge becomes a blur as it rushes past Mach 3, 4, 5 and on up until it slows down, hesitatingly, around Mach 10.

We're cruising along, straight and level, at 8000 mph.

How is it possible? The X-15, on rocket power, does only a little better than 4000 mph—and for very brief periods. Yet the Scramjet will cruise from New York to India in 60 minutes, carrying passengers, or non-stop around the world in less than three hours.

How? Well, it's a combination of old and new technology, and the heart of the whole system is the old ramjet engine.

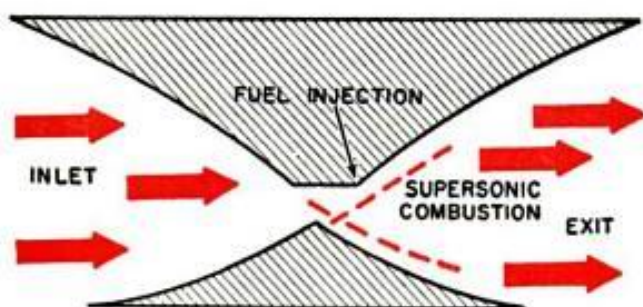
The World War II German V-1 buzz bomb was a ramjet of sorts, and our Bomarc anti-aircraft missile uses a ramjet.

The concept of a ramjet engine is an engineers' dream — it has no moving parts—and they've longed to see it put to more widespread use. As its name implies, it is a jet engine that is rammed through the air. The ramming compresses the air for burning, eliminating the compressor of an ordinary turbojet or the pistons of a piston engine. The ramjet has been

There it goes...
stovepipe



HOW SCRAMJET WORKS



SCRAMJET ENGINE, simplicity itself, has no moving parts, just inlet, combustion area and exit nozzle

called a "flying stovepipe," because it is almost a hollow tube. Air is rammed into the front end, fuel is injected and burned, and the exhaust goes out the rear end. Just that simple.

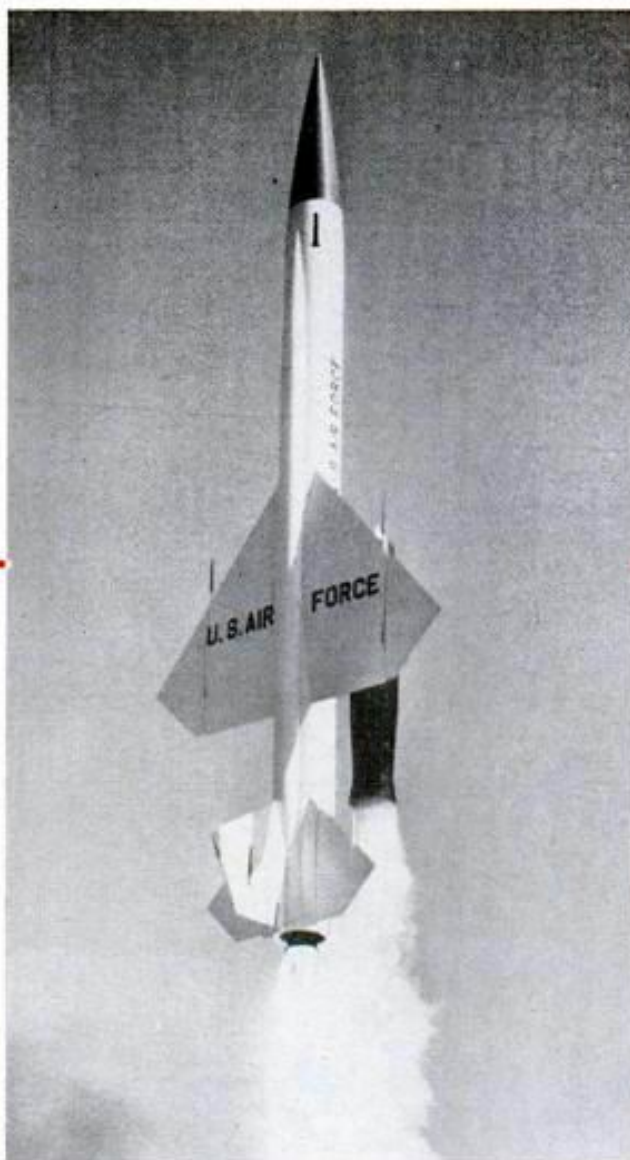
However, such simplicity has obvious drawbacks. The ramjet has to be moved through the air before it can begin functioning, so it needs auxiliary power to get off the ground, probably a turbojet engine. And, until recently, it could not maintain combustion supersonically. The air was rammed in the front end at supersonic speeds, slowed down inside to subsonic speeds for burning, then exhausted. This system, while it produced supersonic thrust up to about Mach 6, created high temperatures (which necessitated bulky construction) and inefficient fuel consumption. So, with isolated exceptions like the Bomarc, ramjets were ignored.

Now comes the Scramjet (for supersonic-combustion ramjet). It isn't built yet, but the Air Force is spending money on it and experts see commercial uses.

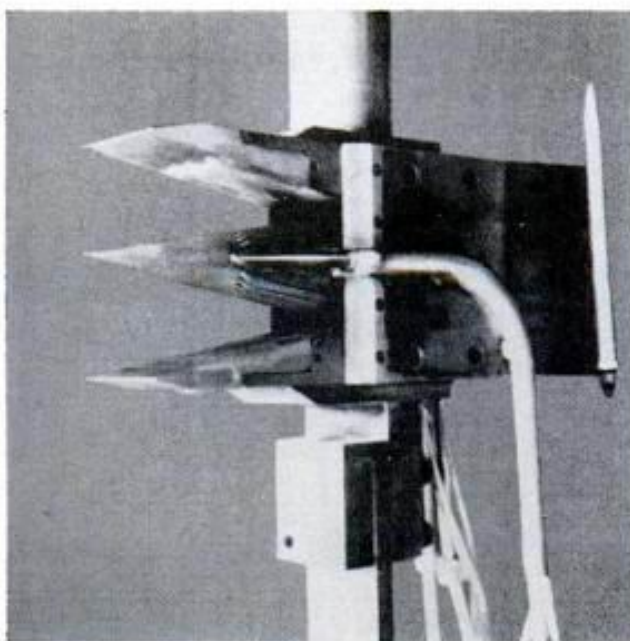
The breakthrough that made it all possible occurred less than two years ago when an experimental Scramjet engine was kept burning with air moving through it at more than 7000 mph.

One spokesman told me, "That's like keeping a match lit in an open-top convertible while speeding along the Los Angeles Freeway."

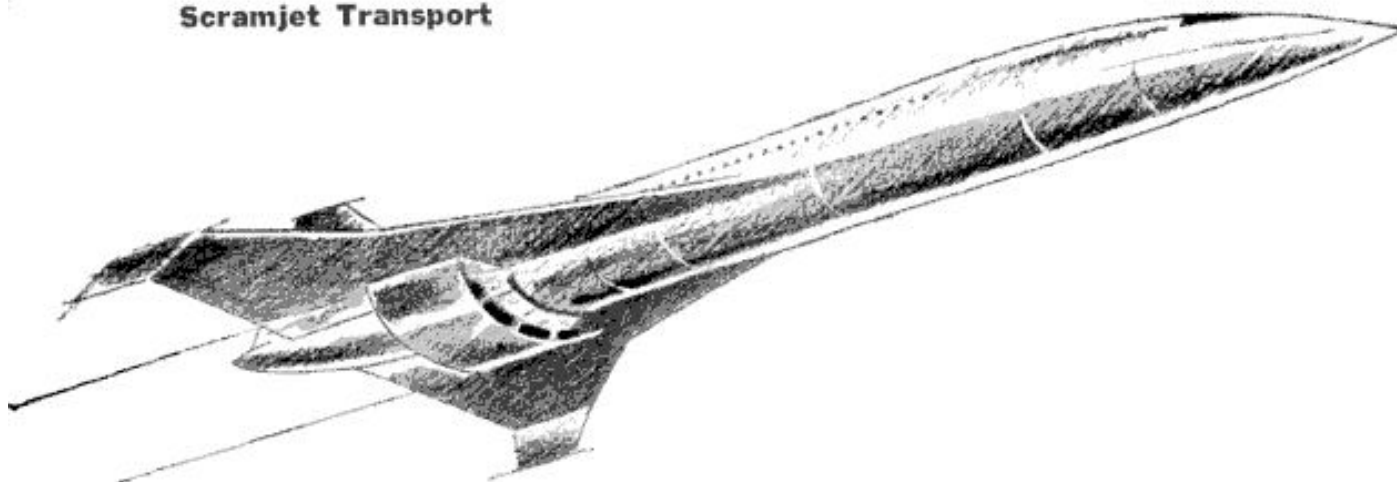
What kept the engine lit was the fuel—liquid hydrogen—and a highly sophisticated fuel-control system. Hydrogen has a low ignition temperature and burns rapidly, so the Scramjet can go back to the simple "stovepipe" type of construction and move through the air supersoni-



BOMARC MISSILE, used as anti-aircraft weapon, is sole current operational use of ramjet engine. It uses auxiliary takeoff power before kicking in ramjet



FIRST SCRAMJET breakthrough was this engine which was kept burning continuously while air was forced through it at speeds clocked in excess of 7000 mph



HYPERSONIC AIRLINER that will carry you at cruising speeds of 8000 mph might look like this. Scramjet engines may be wrapped all the way around the fuselage or just strapped to the underside alone as in SST

cally without slowing the air to burn it.

The Air Force awarded a study contract to the Marquardt Corp., which has made ramjet engines for the Bomarc missile and others, and the first unmanned Scramjet flights should result.

It all begins with the engine. I sat in the Marquardt offices in Van Nuys, Calif., and was briefed on what's planned.

Marquardt's engines will be based on what it calls the modular concept. The engines will be strapped to the fuselage in such a way that the fuselage itself becomes part of the engine, the nose of the vehicle serving as part of the inlet and the tail as part of the exhaust nozzle. The first Scramjets, in fact, will very likely have four or eight of them strapped all around the fuselage. Later, larger versions may have them placed under the fuselage.

They'll work just the way a ramjet works now, with the basic exception that the airstream remains supersonic.

As we said, it's an engineer's dream—a simple, solid piece of machinery with no moving parts. The only problem is to keep that "match lit on the freeway." Marquardt believes it has that problem licked with hydrogen fuel. The fuel, in fact, came with a bonus. Since it must be kept in a supercooled state—minus 425° F.—for maximum efficiency, it can be circulated behind the nose and leading edges of the aircraft to reduce the intense heat of friction.

The dream becomes even more inviting because, apparently, the Scramjet engine becomes more efficient the faster it goes. They showed me the ever-present graphs, comparing efficiencies of turbojets, ramjets and Scramjets at various speeds. The

first two had short and erratic lines, but the Scramjet was a long smooth line all the way out to Mach 20.

The faster it goes, of course, the higher it can go because it will be gulping more air. Scientists believe that the thin air of high altitudes will still be thick enough to support a cruising Scramjet comfortably up to about 160,000 feet.

Meanwhile, back in the metal shops, the boys are coming up with other breakthroughs in other fields. Titanium and columbium are relatively new metals combining relatively light weight with high melting points, and future hypersonic vehicles might be constructed primarily of these and similar alloys.

This parallel development in new metals was a large factor in renewed interest in ramjet engines and their applications in very high speeds of hypersonic flights.

What are some of these applications? Why bother with such extreme speeds? Well, they've been asking much the same questions since before Columbus, before Lindbergh, before the subsonic jets and even now about the supersonic jets.

The military, of course, is always interested in going farther faster. If it doesn't, some aggressor nation might. One Civil War general said it best: You win by getting there "fustest with the mostest."

The Air Force could use Scramjets as reconnaissance or strike aircraft, getting in and out before any enemy even knew they had taken off. A secondary, but no less important, role would be as specialized cargo carriers, transporting small loads of vital parts to strategic areas—parts, like electronic equipment, that, if

(Please turn to page 236)



I was an 18-foot robot

Strapped in place, the author was the steel giant's brain. His motions were duplicated by the robot, but with enormous power

By James R. Berry

MY FIRST TASK was to learn how to balance. Confidently, perched in the body of an 18-foot, two legged robot, I leaned forward. The platform I was standing on, sensitive to my slightest shift of weight, moved too. With a loud sigh of hydraulic valves the automaton I was commanding sprang to life.

Instantly, it mimicked my move. Before

I realized what had happened, it pitched forward out of control. Using my toes for leverage, I frantically tried to stop our headlong plunge by throwing myself backwards. The robot's reaction was as quick as it was violent. Accompanied by a piercing shriek of valves, the automaton shuddered to a halt, then swiftly heaved back. Before I could react, it had crashed down on its heels with a jolt that rattled every bolt in its body.

Able to Rock

More warily now, I tried the maneuver again, this time successfully. After a few minutes of cautious trials, I was able to rock on my feet while the automaton, duplicating my moves, swung back and forth in slow, five-foot arcs. Soon, I could keep the machine where I wanted with a slight pressure of heel or toe.

Now, holding the robot in quivering equilibrium, I bent forward at the waist. The automaton's hips—controlled by a movable metal frame strapped to my back—moved and the machine dipped forward in a polite bow. I bent backwards and the

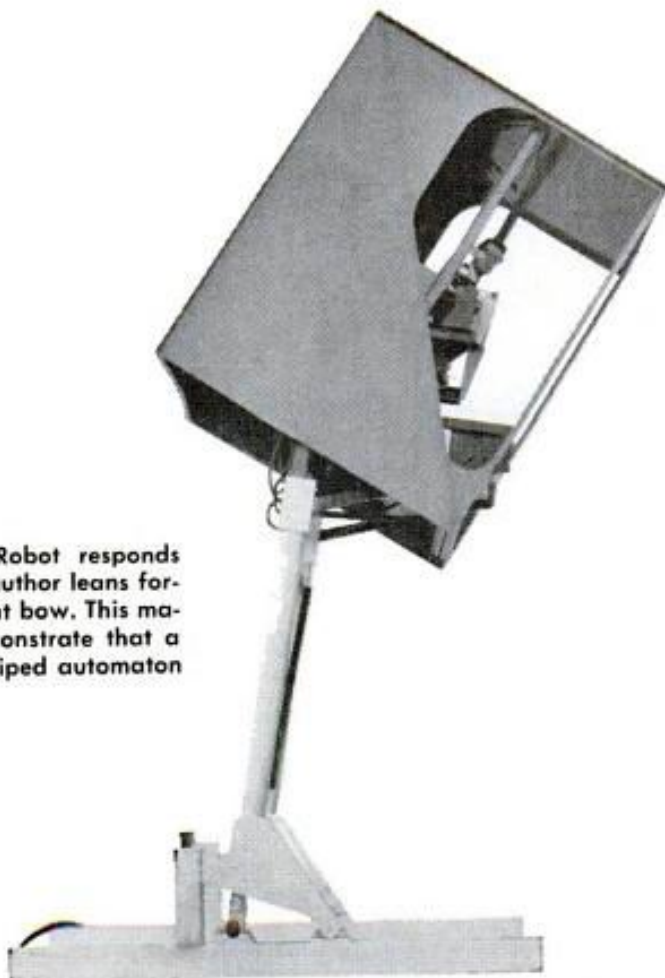
robot obediently did the same. Compared with balancing on my feet, this maneuver was a cinch. Inspired by my success, I raced through all the motions I had learned. The hydraulic system hissed, roared, and wailed as the automaton went through a series of movements as outlandish as the latest discotheque dance.

I was at General Electric's Advanced Technology Laboratories in Schenectady, N.Y., harnessed in the Pedipulator, one of an extraordinary new race of robots with the tongue twisting name of cybernetic anthropomorphic machines—CAMs, for short. This CAM, precursor of a generation of walking automatons, was built to demonstrate that a man can balance a bipod robot. Achieving balance is the first and most difficult part of walking. So, at the moment, the Pedipulator's feet are stationary and its arms, though developed, await being scaled up and bolted on.

What will the fully operating, walking robot actually be like? From the experience I'd just had and from what the GE engineers told me, I could easily imagine the robot at a building site or in a ship-



MONSTER COPYCAT. Robot responds immediately when the author leans forward and executes slight bow. This machine was built to demonstrate that a man could balance a biped automaton



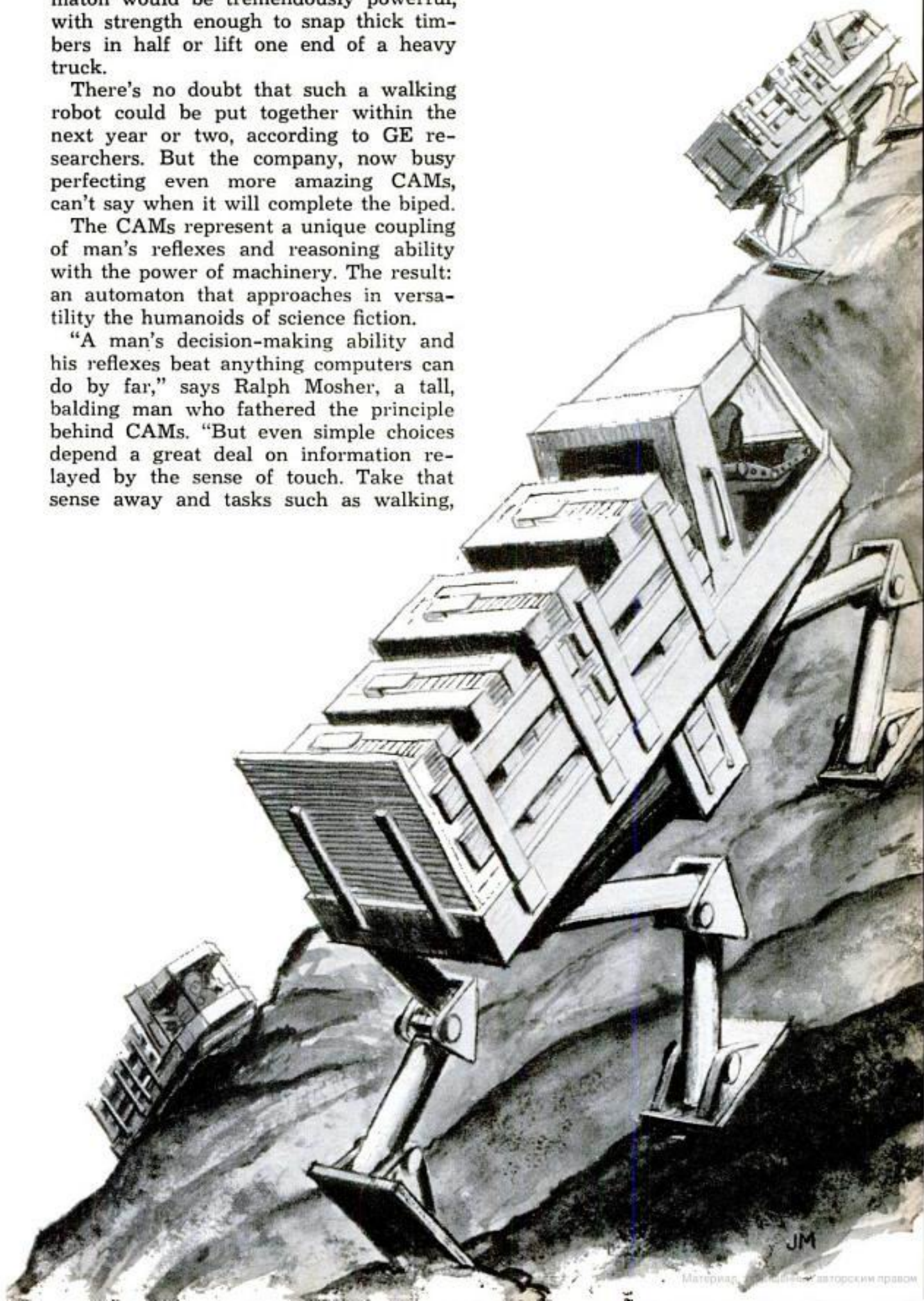
yard, clanging about on heavy steel feet, lifting bulky metal parts into place with its steel arms and making delicate adjustments with pincerlike hands. The automaton would be tremendously powerful, with strength enough to snap thick timbers in half or lift one end of a heavy truck.

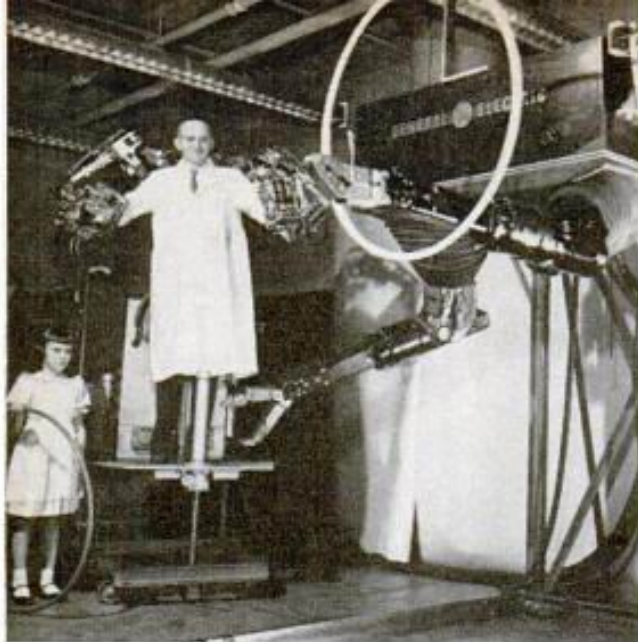
There's no doubt that such a walking robot could be put together within the next year or two, according to GE researchers. But the company, now busy perfecting even more amazing CAMs, can't say when it will complete the biped.

The CAMs represent a unique coupling of man's reflexes and reasoning ability with the power of machinery. The result: an automaton that approaches in versatility the humanoids of science fiction.

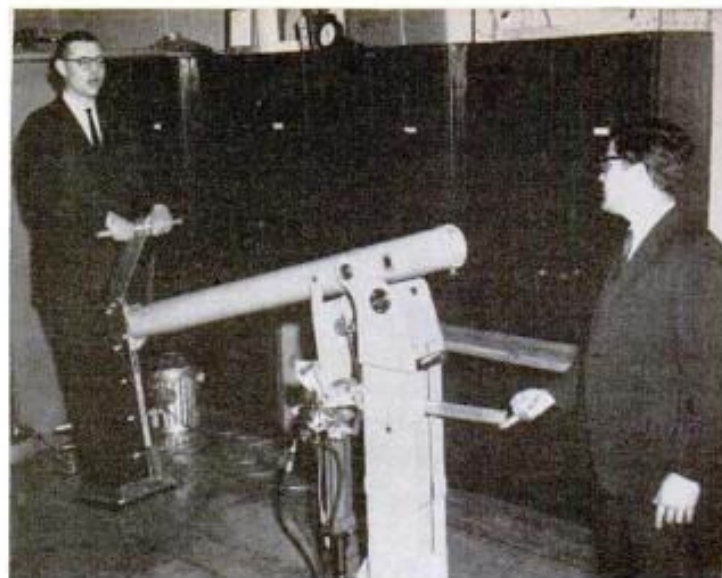
"A man's decision-making ability and his reflexes beat anything computers can do by far," says Ralph Mosher, a tall, balding man who fathered the principle behind CAMs. "But even simple choices depend a great deal on information relayed by the sense of touch. Take that sense away and tasks such as walking,

QUADRUPED ROBOTS, now under development for the Army, would be used primarily as cargo carriers in rough or marshy country, where even tanks bog down





INVENTOR RALPH MOSHER makes Handyman spin hoop. Machinery around Mosher's arms transmits every motion to the robot's arms and pincerlike hands



FINGER PRESSURE applied by author is enough to lift 150-pound man. This boom was used in the development of system for controlling robot's limbs

opening a door, or squeezing a tube of toothpaste become major problems."

CAMs incorporate a sense of touch. By a system called force feedback, the operator of a CAM feels the strains and stresses in the robot's limbs and body as though they were his own. The operator's arms, legs, and body are strapped into mobile, jointed frames called follower racks. Like an external skeleton, the follower racks pick up his every move, causing a corresponding, but amplified, motion in the CAM's analogous limbs and body.

But the follower racks serve another purpose. As the CAM does work, from balancing itself to carting boulders, its joints undergo stress. Part of this stress is hydraulically fed back to the follower racks, causing a proportionate strain in the operator's muscles. A simple adjustment increases or diminishes the amount of stress the operator feels.

Although CAMs haven't yet reached the stage of assembly-line production, they're already being eyed for scores of jobs that demand the reasoning power and dexterity of a man and the strength of a bulldozer. Some possible applications:

- Builders could use CAMs to lift steel girders into place, raise walls of prefabricated houses, tote materials around a construction site. CAMs with steamshovel-sized scoops replacing hands could dig tunnels, basements, or trenches, easily maneuvering where ordinary equipment couldn't be used. They would be especially helpful in archeological excavation where

their delicate sense of touch would be invaluable in uncovering ancient towns without damaging structures and artifacts.

- After disasters, CAMs could replace telephone poles, string cables, stack huge sandbags, and remove tons of wreckage at a throw. Others might simply wander through an emergency area on the lookout for survivors and remove them to safety.

- CAM artificial limbs might be linked to nerve centers and muscles in the stump of an amputee. The Woodrow Wilson Rehabilitation Center in Virginia is looking into just such a possibility. If successful, such limbs would pass a sense of feeling to remaining muscles, perhaps even to the nerves.

- Shipyards, auto and aircraft plants and other heavy manufacturing centers could use CAMs to assemble big but sensitive equipment. At piers, truckyards and rail terminals, CAMs could unload and load tons of cargo in a trip, putting it in place as easily as a child stacks blocks.

Improvements already envisioned would extend the range of the CAMs' usefulness even more. "There's no reason why the operator has to be inside his CAM," explains Mosher. "You could link the two by radio." Such a system, while probably at least a decade away from perfection, has incredible possibilities.

A remote-controlled CAM, for instance, could reconnoiter the ocean's floor, noting geological formations, locating mineral

(Please turn to page 202)

MAN AMPLIFIERS:

Superman suit is modeled by the author at Cornell Aeronautical Lab, Buffalo, N.Y. Joints will be powered to multiply the wearer's strength as structure follows his movements.



Machines That Let You Carry a Ton

Strap on the "exoskeleton" and your strength is multiplied many times over—you'll be able to handle a ton with all the flexibility of human muscle power

By WALLACE CLOUD/PS Science Editor

When they strapped me into the superman suit, I felt like Frankenstein's monster getting up off the operating table.

I clonked around the room like a gorilla, with this 35-pound jointed "exoskeleton" hanging onto me.

"Why are you bent over like that?" said Neil Mizen, the project engineer at Cornell Aeronautical Laboratory.

I straightened up and discovered that I could move freely, even though the exoskeleton didn't have quite as many joints as I

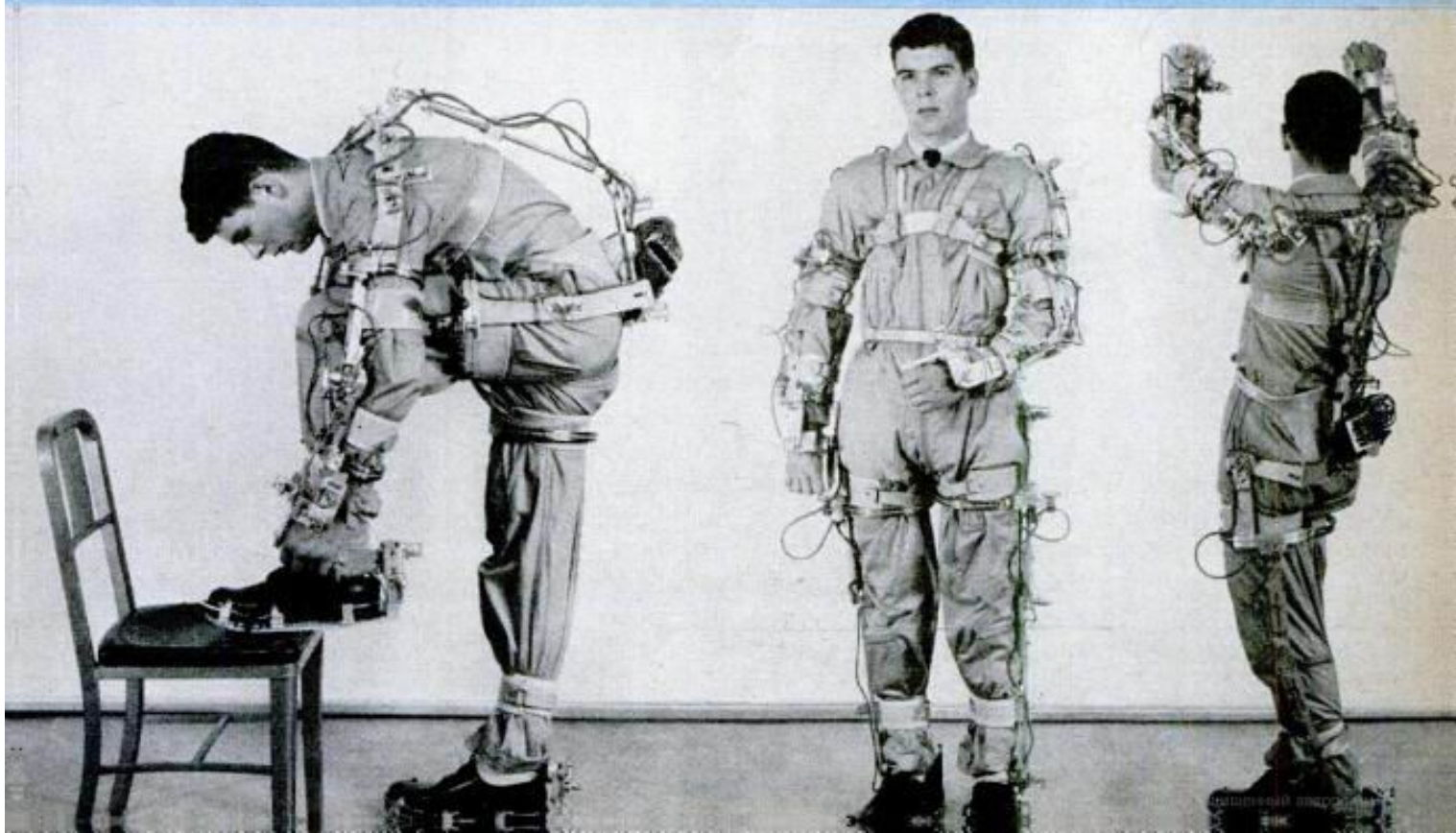
did. It wasn't up to some of the intricacies of the frug, but it followed me pretty closely.

The next step will be to put hydraulic motors at all the joints, and then it really will be a superman suit. Wearing it, any normal person will be able to heft 1,000 pounds—with each hand. You'll be able to carry a ton like a sack of groceries.

You'll have an 80-pound power pack on your back—a 20-horsepower gasoline engine plus fuel tank. But you won't be carrying it. The powered exoskeleton will be.

Continued

Flexibility of exoskeleton, wired to record motion, is shown by technician Ronald Patterson.





First uses of the exoskeleton are expected to be military. Here, a GI in a superman suit unloads munitions at a jungle helicopter landing field.



Superman-suited construction worker positions a heavy valve on site of a chemical plant—one of many civilian uses foreseen.

and it will also be supporting its own weight of about 400 pounds.

What a nutty idea, I thought when I first heard of it. But it turns out this is no joke. It's being developed for the Office of Naval Research.

The Navy wants the superman suit to help sailors manhandle torpedoes, bombs, and machinery in the cramped quarters aboard ship and in submarines. The exoskeleton could take the place of any number of hoists, overhead cranes, and other special-purpose weight-lifting equipment.

The Air Force and the Army are also interested. Exoskeletons would be useful for unloading and handling cargo and weapons in rugged terrain such as the jungles and rice paddies of Vietnam, and for construction work where a lot of specialized machinery is not available.

Multiplying muscle power. Cornell's exoskeleton is one of several "man-amplifier" projects underway in the U.S. Although there are differences, the basic idea is to put a man inside a machine that will duplicate his movements, but with greatly amplified strength and endurance.

One of these is the well-known "pedipulator," or walking machine, which GE has been developing for several years. This 18-foot-tall monster would walk on jointed legs, duplicating the movements of a man standing inside a cab at the "hips" of the

machine. GE is working on the legs now, planning to add powerful arms.

A number of laboratories are doing research on controlling such machinery with "myoelectric" signals—electric currents generated by the muscles. The signals can be detected by means of electrodes taped to the skin. This research is aimed largely at developing better artificial limbs for amputees, but myoelectric signals could provide fast, sensitive control of man amplifiers.

When production models of man amplifiers are available, it's unlikely that they will be limited to military use. In factories and construction work, man amplifiers, perhaps costing only a few thousand dollars, will be able to do more things than present materials-handling equipment. They will be able to operate without special installation or site preparation, and will also make it possible to move and manipulate heavy objects with delicacy and precision.

Some tricky problems remain to be solved. At Cornell, project engineer Mizen explained, the approach was to build an unpowered exoskeleton that would cling to a man, to see what kind of strength-increasing structure could be built, and how many joints it would need and how they would have to move. The one I tried on was the result.

It was built to the measurements of

[Continued on page 204]

military and civilian—are limited only by your imagination

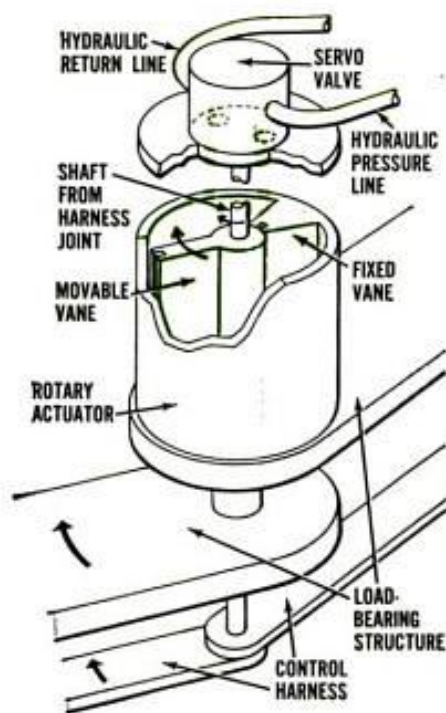


Exoskeleton can be made bigger or smaller than the man in the control harness. Here, a giant version replaces a derailed ore car at a mining site.



A miniature version, exposed to radioactivity, works to free jammed control rod of a nuclear reactor as operator watches on a TV monitor.

Next phase of development: applying power to the joints



Acid test of Cornell's exoskeleton design is whether power applied to the joints can be controlled precisely by the wearer. Mock-up shows sizes and locations of the hydraulic motors or actuators that will power the exoskeleton's arms and shoulders. This load-bearing structure will be linked to a harness like the unpowered exoskeleton shown on preceding pages. How each harness joint controls the corresponding joint of the structure is depicted in the diagram, an exploded view of the hydraulic actu-

ator and servo valve attached to the joint. Movement of the harness joint is transmitted by its shaft to the servo valve atop the actuator. The valve regulates the pressure of hydraulic fluid on each side of the movable vane in the actuator. Movement of the vane is conveyed by its shaft to the structural member, positioning the structure joint so it corresponds to the position of the harness joint. Some pressure is fed back through the valve, so the wearer knows the position of the structure.

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By ERLE STANLEY GARDNER

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OF THE MONTH**

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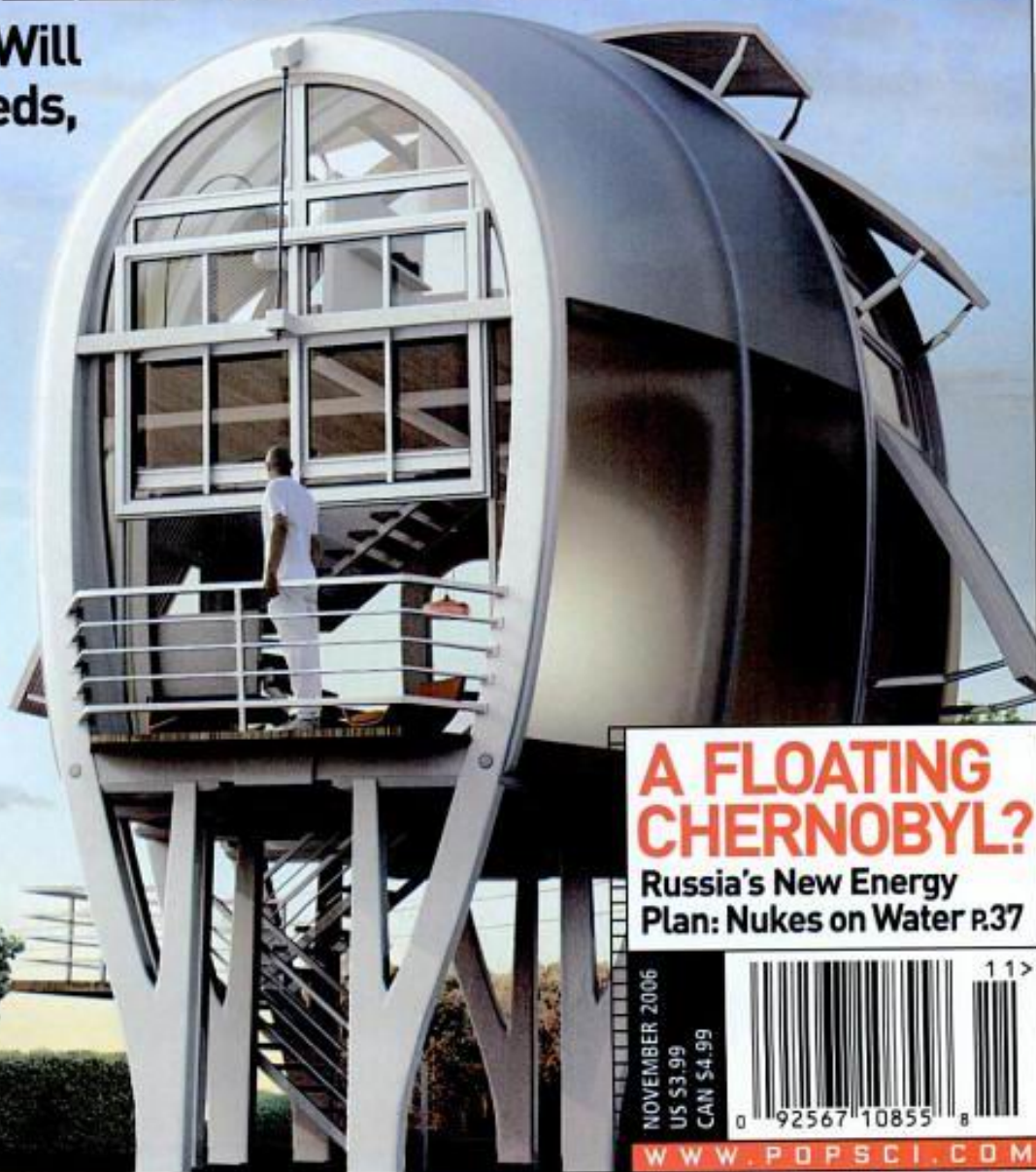
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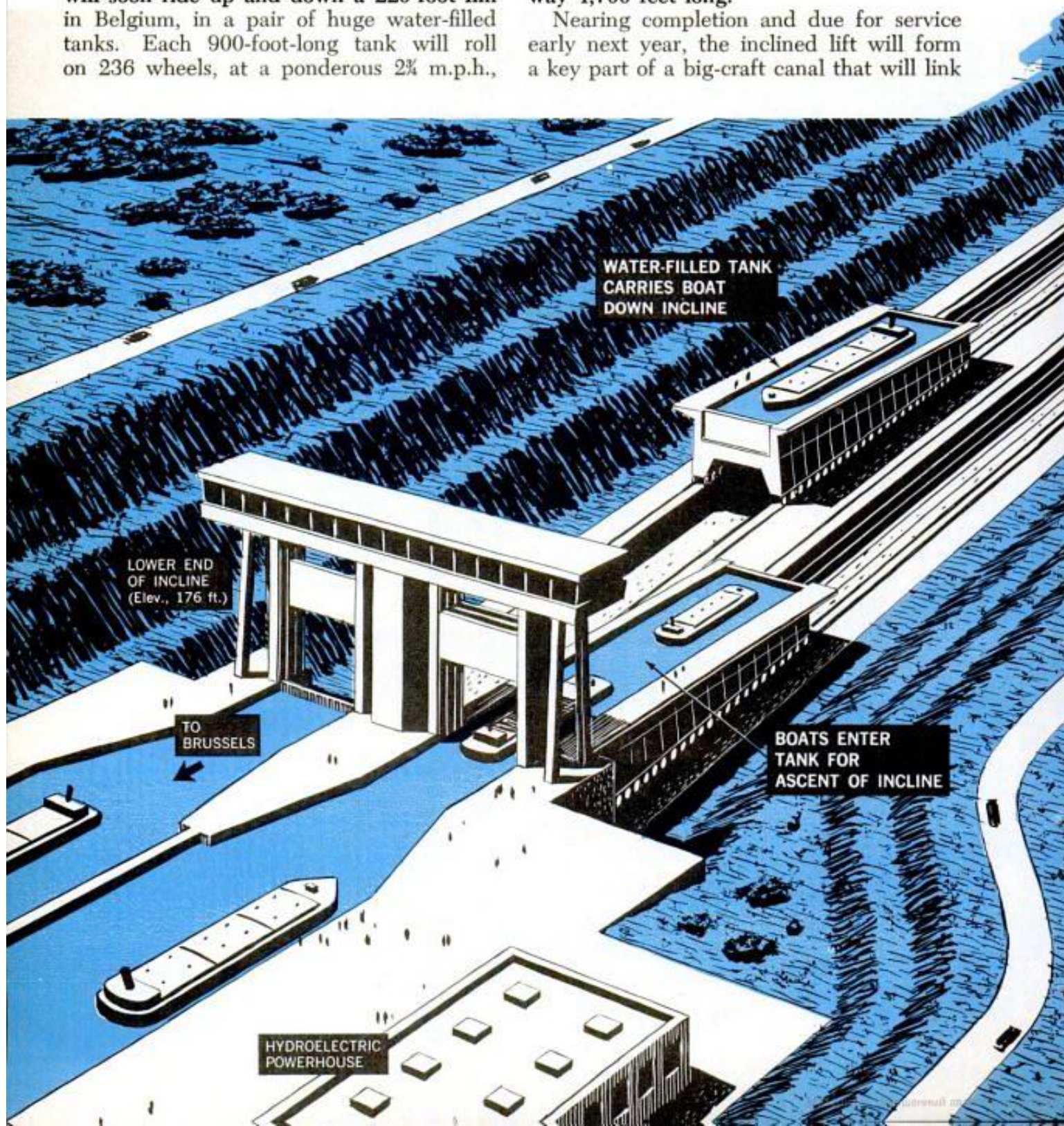
Ships Float Uphill and Down

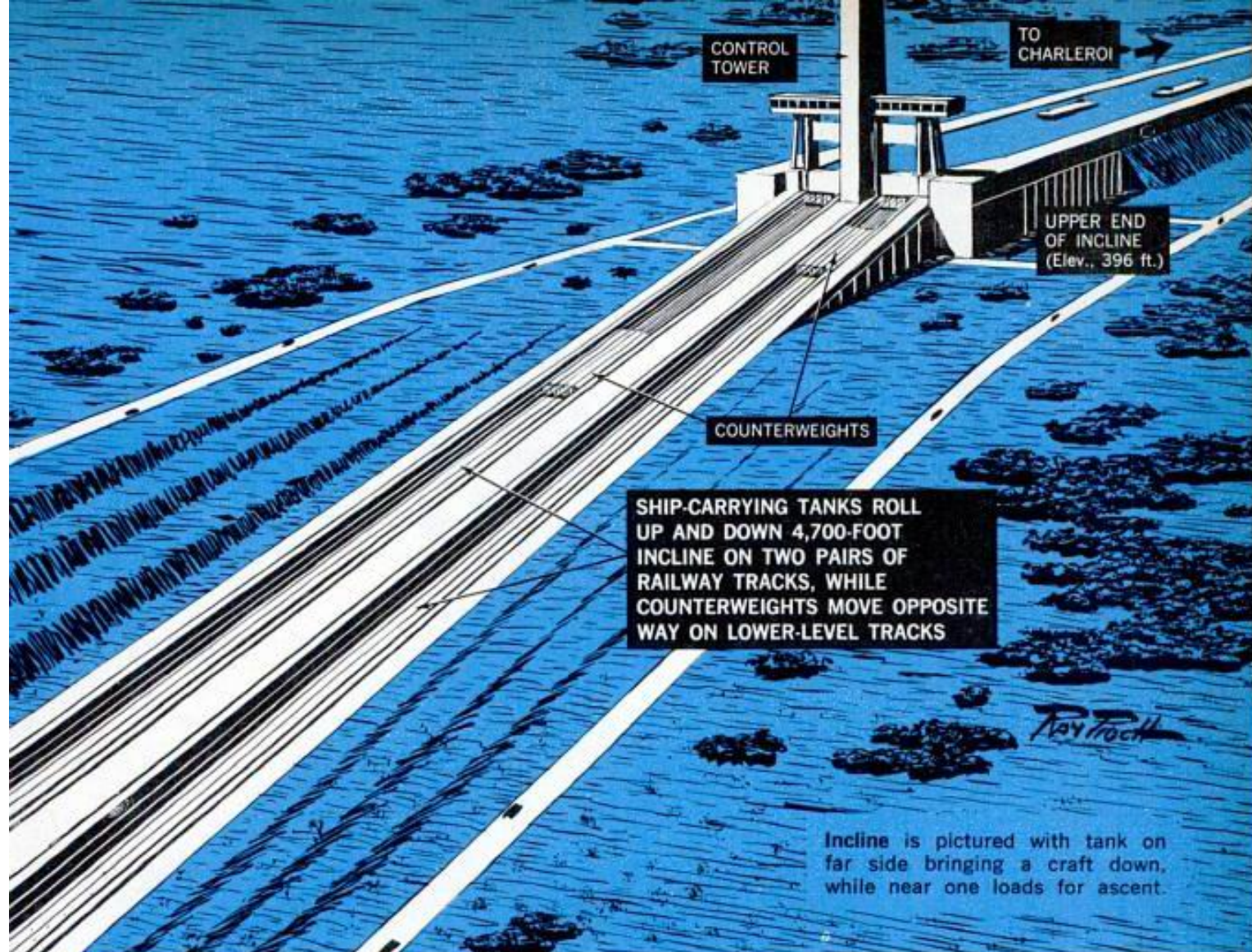
An inclined railway hauls big canal boats over the hill in water-filled tanks

Canal boats as big as 1,500 tons will soon ride up and down a 220-foot hill in Belgium, in a pair of huge water-filled tanks. Each 900-foot-long tank will roll on 236 wheels, at a ponderous 2½ m.p.h.,

along a four-rail track on an inclined railway 4,700 feet long.

Nearing completion and due for service early next year, the inclined lift will form a key part of a big-craft canal that will link





Incline is pictured with tank on far side bringing a craft down, while near one loads for ascent.



How incline works: To ascend 220-foot hill, canal boat successively approaches incline, enters tank, is hauled up incline in tank, reaches top, and pro-

ceeds on way. Counterweight (shown in midway position only) balances most of tank's weight. Electric-powered hoist does the rest.

industrial Charleroi with Brussels and the seaport of Antwerp beyond. The new waterway will shorten the winding route of a present small-boat canal and eliminate most of its dozens of locks.

When one of the lift's tanks has been latched to the end of the lower-level canal, and gates are raised, a canal boat is floated right into the tank. Then gates are lowered, the tank is unlatched, and tank and craft are hauled by cables up the five-degree slope. The tank latches to the end of the upper-level canal, gates are raised, and

the boat goes on its way. Reversing this procedure serves for descent.

The two tanks move independently. Their wheels are flangeless to minimize friction; to keep them on the track, extra guide wheels bear against side rails. Counterweights balance most of the tanks' weight and keep the power required for each tank's hoist to a reasonable 1,020 hp., provided by six 125-kw. electric motors. Excess canal water, flowing from the upper level to a hydro plant below, generates the needed current.—David Scott.

500 — 300 — 200

That's horsepower, miles per hour and thousands of dollars: the oversize numbers for **Dodge's 4-wheel Tomahawk** "motorcycle" prototype (named for the cruise missile), which the company says it may bring to market.

BY DICK TERESI

PHOTOGRAPHS BY DAVID DEWHURST



SPECS

Dodge's 4-wheel Tomahawk

BODY STYLE:
Single-seat Viper-
powered motorcycle

BODY
CONSTRUCTION:
Billet aluminum

OVERALL
LENGTH: 102 in.
WHEELBASE: 76 in.
CURB WEIGHT:
1,500 lbs.

ENGINE: 8.3-liter

ohv 20-valve V10

TRANSMISSION:
Manual, foot-shifted
2-speed

WHEELS: 20x4
(front), 20x5 (rear)
billet aluminum disks

TRUE TOP SPEED:
To be determined

The biggest news out of DaimlerChrysler this spring is not a sport-utility vehicle or a sports car. It's a motorcycle. A big, weird motorcycle.

The Dodge Tomahawk is auto erotica for the customizer and power freak. An enormous 500-horsepower V10 Viper engine sits on a billet aluminum body, each part a one-off custom design, machined to order. The exhaust note reminds us of a light aircraft's, with enough crackle to rattle windows.

A noticeable departure is the four wheels. OK, a four-wheeled motorcycle is an oxymoron, but in this case the wheels are closely paired, giving the vehicle a motorcycle appearance if you squint hard. Dodge sees the four wheels as an advantage, noting that the bike stands up on its own. (Customers willing to shell out \$200,000 should be happy to learn that they won't need to buy a kickstand as well.)

So what happens to this 4-wheeler when you lean into a turn? Similar designs have rolled up on just two tires when banking, then dropped back onto all four when the bike straightens out, sometimes with uncomfortable results. Thanks to an inventive suspension, all four of the Tomahawk's tires remain in contact with the road even when the bike is cornering. Yet it's no car. You lean and counter-steer, just like on a bike.

The bike's name was inspired by the Tomahawk cruise missile, and it may be equally rideable. Dodge first announced a top speed of 420 mph, then dropped that to "300+." DaimlerChrysler spokespeople proved unable to illuminate us further. Can we ride the bike to check the speed? we asked. "No." Can we talk to



one of your company riders? "No." Can you give us some riding impressions? "No." Can we use your bathroom? "No."

Desperate for expertise, I called my brother, Joe Teresi, whose Easyriders Streamliner bike holds the world speed record: 322 mph on the Bonneville Salt Flats, set in 1990. Looking at photos of the Tomahawk, Joe was dubious. Dodge computed the Tomahawk's theoretical top speed only from horsepower and final drive ratio. Joe says this ignores other critical factors, such as frontal area and drag and the coefficient of tire friction to the ground.

Joe offered Dodge the use of his Dyno-Drag, a motorcycle dynamometer/simulator, to ascertain the Tomahawk's top speed. When I relayed the offer to Dodge spokesman David Elshoff, he said, and I quote, "No." Elshoff did say Dodge would someday take the Tomahawk for a run at Bonneville.

Dave Campos, who was onboard the Easyriders Streamliner for the world record, predicted the Tomahawk wouldn't do well in the real world—and that the rider would do worse. The Teresi/Campos bike was powered by two 91-cubic-inch Harley Shovelhead engines and enclosed in a fairing. The Tomahawk Viper engine is 505 cubic inches; the rider is exposed. Campos said he would be foiled by air resistance. At high speeds, "your back acts as a wing. It'll lift you right off the bike." Campos was also skeptical about the four-wheel steering, and said he doubted the bike would hit 200 mph. Still, he wishes the Tomahawk team luck at Bonneville. "Let nothing but fear stand in your way," he said.

Many bikes today are built for show, not go, and even if the Tomahawk never breaks 55, there are a lot of guys who'd like to trailer it to Sturgis or Daytona during Bike Week just to fire up that motor and drown out the Harley crowd. Or, as my brother says, "It's a nice engine stand for your Viper V10." ■



HOW DESIGNERS CREATED THE 500-HP 4-WHEEL SUPERBIKE

IT WAS ALL FOR POWER. The Tomahawk's designers were so bent on making a brutally powerful motorcycle that they were forced to mutate most of the bike's components to accommodate the massive V10 Viper engine. Take the gas tank (1A): To shield it from the engine's heat, they had to relocate it to the front fender. Two standard tires couldn't handle the power, so to keep the 4-wheeler feeling like a bike, designers devised a unique independent suspension.

Expense, obviously, was no concern. Almost everything on the Tomahawk, from the blue anodized brake calipers (1B) to the valve covers, was custom-made from huge blocks of aluminum milled down to size (imagine carving a pencil from a redwood tree).

All rockets go fast, but stopping them is another matter. The disc brakes, sporting 16 pistons in the front and eight in the back, take the job seriously. The drilled brake rotor (1C) is mounted on the edge of the wheel rim, while the calipers connect to a central crescent-shaped hub (1D). Designers linked the wheel to the frame with a double horizontal fork (1E) for more than just cosmetics: During strong acceleration and braking, the forces acting on the fork are parallel to the ground. A vertically aligned fork could snap if this force is too great, whereas a horizontal fork easily absorbs the stress. It's much like a nail: easy to bend when you hit it from the side, strong and incompressible

when you strike it squarely on the top.

The seat (2A) and panels underneath it (2B) started life as 1,500 pounds of block aluminum. Together they now weigh just 70 pounds. Riders brave enough to climb aboard adopt a semi-prone position, drag-racing style. The battery is nestled inside the seat, while the panels cover the 2-speed custom transmission (you don't need a low gear when you've got 525 lb.-ft. of torque). Two drive chains designed for forklifts transmit power to the rear wheels.

The suspension was tricky. All four wheels are independently controlled, the front with double arms (3A), and the rear with a trailing arm. These enable the rider to lean up to 45 degrees into a turn while keeping all four wheels on the ground. To prevent the bike from falling over when parked, a switch locks the rear suspension, creating a de facto kickstand.

The headlights (3B)—12 in all—sit between the front wheels. Each is a 5-watt LED with beam-modifying optics. Eight of them make up the taillights. Two air intakes (4A) oxygenate the fuel, and a forward fan (4B) sucks air into the radiator, where two banks of 18- by 8-inch cooling fins dissipate the engine's heat. Placing the radiator on top of the engine, where the gas tank usually is, also helps insulate the engine from the rider. Even the tires are custom-made; if Dodge can find a wide enough tire, the bike could become a two- or three-wheeler. —MARTHA HARBISON



World's largest radio telescope

gets sharpened
vision

This monster dish can reveal our atmosphere, the planets, and the universe—with breathtaking precision

By ED EDELSON

ARECIBO, P. R.

When I rode the cable car to the antenna platform of the radio telescope at Arecibo, Puerto Rico, I was scared to death. I am afraid of heights. The cable car is an open wire basket, no more than chest high. The platform hangs 500 feet above the telescope's reflector, suspended by cables—to my eye, having no visible means of support. For me, the ride was white-knuckle time.

But when I reached the platform, my fears vanished, defeated by the sheer immensity of the structure. It was really hard to be scared on something that big and that stable. The platform—each of its triangular sides 216 feet long, with a total weight of 600 tons—was firm as solid ground under my feet. After a while, I even began to enjoy the view.

Only later I realized that it was this very solidity that brought me to Arecibo. The occasion was the resurfacing of the telescope's reflector to upgrade its capabilities manyfold. And that upgrading was possible only because the platform was much more stable than its designers had planned.

For scientists at the observatory, the improvements mean a whole new set of ballgames they can play with the planets, the stars, the galaxies, and the multitude of molecules in the vastness of inter-



stellar space far from this galaxy.

Used as a radio telescope, the big dish will not only be able to find and analyze such radio sources as quasars and pulsars, but will also be able to seek out complex molecules in the void *between* stars, a capability that comes with the telescope's new ability to receive shorter wavelengths.

Used as a radar instrument, the observatory will be able to reach across millions of miles of space to make amazingly precise maps of Venus and Mercury, to explore the rings of Saturn, to study the asteroids that orbit between Mars and Jupiter, to bounce signals off the satellites of Jupiter. Indeed, radio astronomers at Arecibo find they have an embarrassment of riches.

"The problem now is that we

Continued

Arecibo radio telescope is built into a Puerto Rican mountain valley, which was scooped out to hold the 1000-foot dish. Antenna platform, seen (overleaf) against night sky, is supported by 3.25-inch woven-steel bridge cables running from three towers surrounding the valley. Platform, capable of holding up to eight antennas, weighs 600 tons and hangs 500 feet above the dish, yet is held to less than one-inch sway despite wind and weather. Such stability is needed to permit the telescope's precision exploration of the earth's ionosphere and the universe beyond. The giant (nearly 20-acre) reflector—recently resurfaced with perforated aluminum panels to upgrade telescope—is also built to fine tolerances. Size of dish is dramatized by photo (above) of workers making fine adjustments that will bring dish to within three millimeters of a perfect sphere. White rectangles are vinyl plates to be used in a new laser ranging system that will automatically adjust the dish.





Hefty bridge cables lend remarkable stability to Arecibo's antenna platform.

are about the only facility that can do these things," says radar astronomer Rolf Dyce. "If you want to do outstanding work in radar astronomy, you have little choice but to come here."

In addition, the observatory will be able to improve its continuing exploration of the ionosphere, the changing bands of charged particles in the upper atmosphere. The ionosphere scientists can get more sensitive reception of the echoes from signals they bounce off the ionosphere, and can send more powerful pulses of energy into the ionosphere to create temporary disturbances whose slow dissipation is a lesson in plasma physics.

And if any civilization out there wants to talk, Arecibo is ready to listen: A message to intelligent beings in outer space was sent as the highlight of the telescope's rededication ceremony last November. Mankind has sent inadvertent radio messages into the universe, in the form of ordinary radio and television broadcasts, and two written messages, the plaques on Pioneers 10 and 11, which won't leave the solar system for years. But the Arecibo message (see box in this article) was the first planned radio message to other civilizations.

All of this was made possible by a set of engineering and design feats roughly comparable to building the Empire State Building to a tolerance of thousandths of an inch and then guaranteeing its stability to tenths of inches despite any variations in wind and weather.

It seemed the height of daring

in 1958 to propose turning an entire valley into a radio telescope whose dish was 1000 feet in diameter. But in the decade that followed the telescope's inauguration in 1963, it turned out that the designers had not been daring enough.

"We anticipated that the platform would move around in the wind an inch or two," explained Frank D. Drake, director of the National Atmosphere and Ionosphere Center, a Cornell University group that operates the telescope. "The reflector was made with a similar accuracy. But it turned out that the platform is stable to an eighth of an inch, so we could capitalize on that to improve the reflector."

The dish gets 'polished'

What they did was to replace the dish's original open wire mesh with aluminum panels, 38,778 of them. The effect was to make the telescope sensitive to shorter wavelengths than before, and to increase the antenna gain about seventeen-fold.

That's exactly the same as putting an extra-high polish on the mirror of a light-receiving telescope. A radio telescope is designed to receive the same electromagnetic radiation as a light telescope, only in much longer wavelengths, so much longer that huge dishes are needed to achieve even a fraction of the resolution possible with good light telescopes. Make a smoother radio dish, as they've just done at Arecibo, and you get a clearer image.

Scientists at Arecibo know they have a unique instrument to work

with, and they're proud of it. They acknowledge its one drawback: A dish that big can't be made movable, as most radio telescopes are, so it sees less of the sky. In every other respect, size is a virtue, giving mankind an unmatched eye on the universe. Indeed, the Arecibo telescope can exchange messages with a similar-size instrument anywhere in our galaxy.

That wasn't what William E. Gordon, then a professor of radio engineering at Cornell University, had in mind when he proposed building the giant reflector in 1958. Gordon, who has since become dean of science and engineering at Rice University, wanted only to build an instrument for exploring the ionosphere by bouncing radar signals off electrons; an unusually large dish was needed because the proposed target was so small.

Gordon took his supersize idea to the National Science Foundation, which thought about it and then accused him of thinking too small. Gordon was advised to upgrade his cost estimate to include a radio astronomy capability. He did, and the money came through, some \$9.3 million by the time construction ended in 1963. (The recent improvements cost another \$8.8 million.)

Finding a site was the first job. They needed a valley of the right size and shape. Aerial mappers reported that there were some bowl-shaped valleys that could hold a 1000-foot reflector, but not many—one in Hawaii, one in Cuba, three in Puerto Rico. The designers picked Arecibo, actually a valley about 10 miles inland from that coastal city, and moved in to scoop away some earth here, add some there, to achieve the perfect spherical shape they needed. (The parabolic shape of optical telescope mirrors focuses to a single point; it is thus useable only when the mirror can be shifted. The spherical shape of Arecibo's reflector permits observation of about 39 percent of the sky, using movable antennas that are shifted to different focal points.)

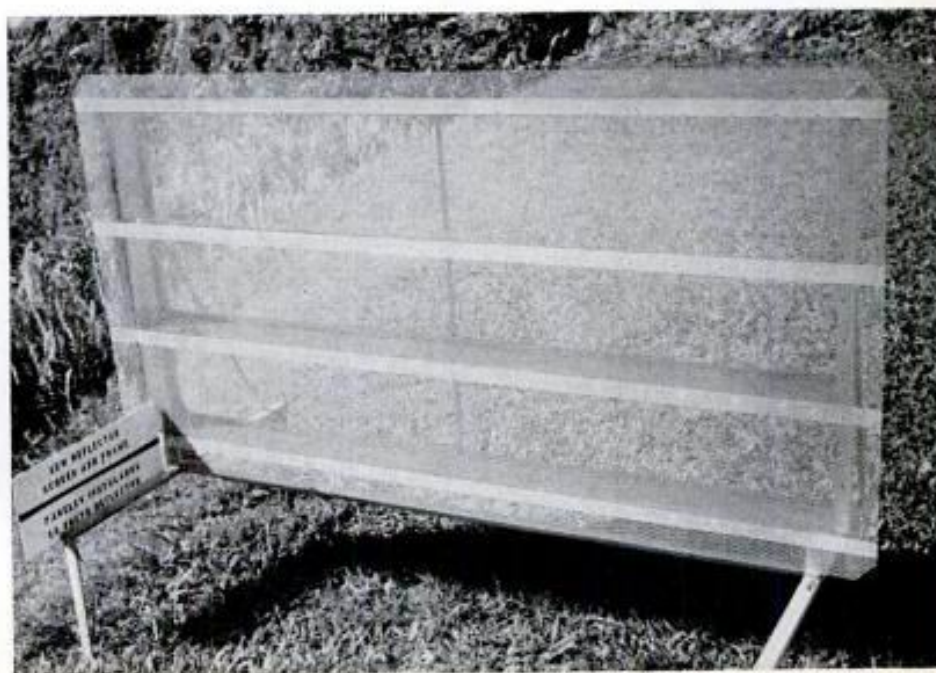
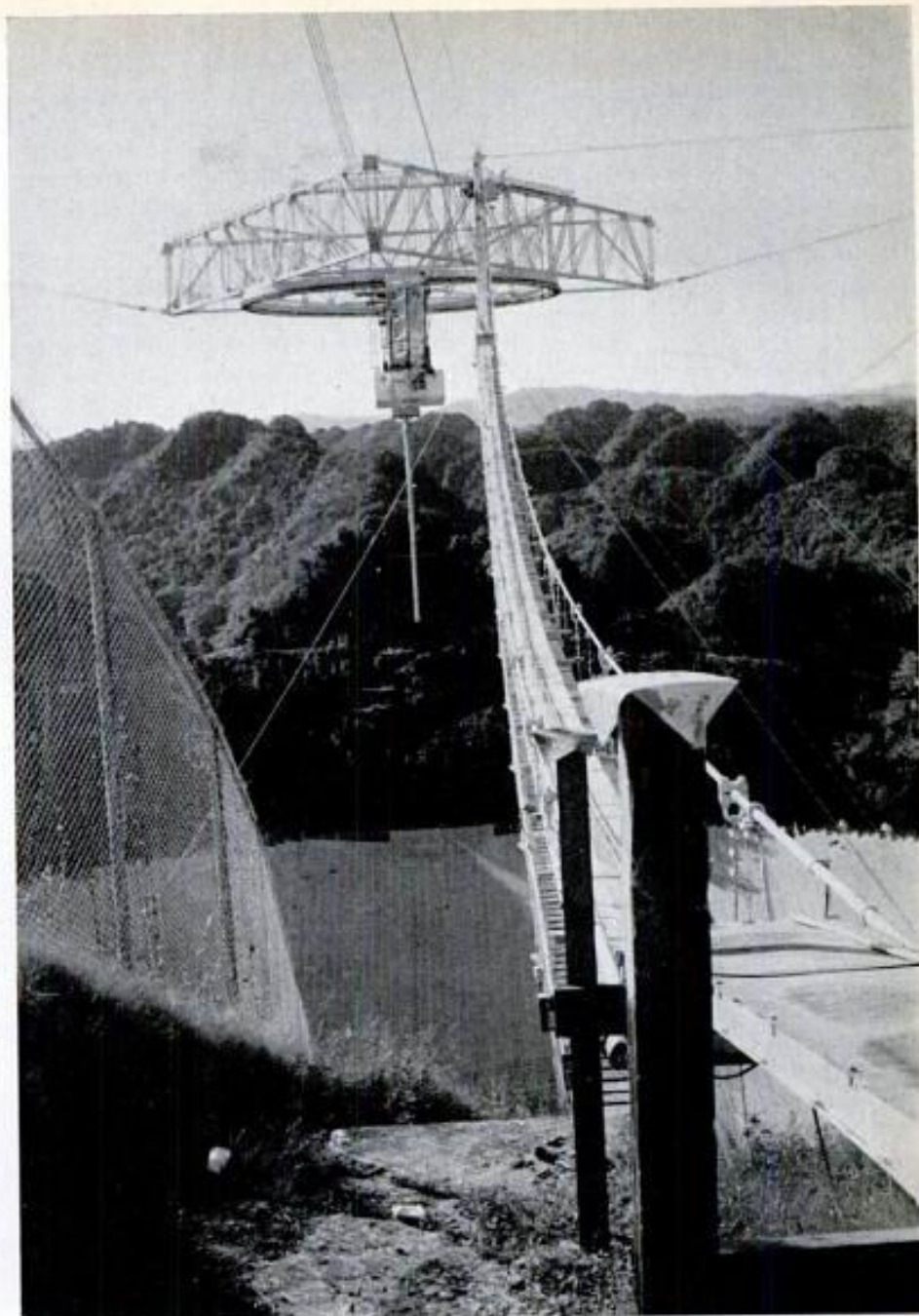
Perfection was (and is) the goal, obviously not easy with a structure that size. Aside from such considerations as wind, the builders also had to allow for the tendency of metal to expand and contract with temperature changes. One reason for choosing Arecibo was its stable climate; the valley has a maximum temperature swing of only 20° F year-round. Even that

Continued

Antenna platform dominates view from control room (below) sited at rim of valley. Catwalk (right) is used by workmen and scientists to reach platform. Antenna on platform is 96 feet long, largest used on the telescope. Graduate student Stephen Spangler, in control room, makes final calibration of telescope controls for study of flare stars.



Wearing special footgear, worker adjusts panels that make up new reflector surface. Sample panel, right, shows holes that let sunlight through to keep vegetation alive beneath dish.



moderate change called for careful planning.

It's all done with wires—more accurately, cables—of the kind that bridge-builders use. The reflector itself is hung from a network of cables attached to a circle of concrete posts that rim the valley. Originally, there were 10 cables to support what Harold D. Craft, Jr., the observatory's present director, called "the glorified chicken wire" of the original bowl. Now there are a total of 29 cables to support the perforated aluminum plates that form the new surface. (The perforations are there to pass through 44 percent of the sunlight falling on the dish, so that erosion-preventing vegetation can continue to grow under the bowl.)

Those 29 support cables are tugged into the proper spherical shape by a network of hundreds of tie-down cables that are attached to a forest of concrete posts embedded under the reflector. Craft explained, "When the temperature goes up, the main cables expand, which means they allow the reflector to sag. But the tie-down cables also expand, and that allows the reflector to rise."

Such payoff of counteracting tugs gives only a crude control method. To reach the needed precision, Craft explained, there is a network of aluminum cusps, one at each corner where four aluminum panels meet, connected to the tie-down cables by an adjustable bolt. An adjustable bolt on each cusp allows the fine adjustments for the final precision.

Right now, the adjustments are ordered on the basis of measurements made by standard surveying theodolites, six of which are mounted on the dish. Their measurements go into a computer, which orders the final corrections.

In the works is a more sophisticated system that will use a four-watt argon-ion laser mounted on a corner of the antenna platform. The laser beam would be split into four sub-beams, three of which are aimed at permanent targets on the reflector rim. The fourth beam can be aimed at any one of 38,778 white vinyl targets, one for each panel. Readings from the laser go to a minicomputer that gives a reading within one minute. The expected precision of this system is less than three millimeters, or about a tenth of an inch, on a surface that covers nearly 20 acres.

It's the same story with the antenna platform, which is suspended on cables run from three symmet-

rically spaced towers, one 365 feet high and two 265 feet high, set on hills around the valley. The towers, whose tops are at the same height, are each anchored by five woven steel cables, 3.25 inches in diameter, that run back to concrete foundations firmly embedded in the ground.

That's just the start. Running from each of the platform's corners are two tie-down cables, which in turn are supported by light carrier cables, an ingenious system proposed by Cornell astronomer Thomas Gold to reduce the tie-down cables' sag and increase their stability. Again, there's a payoff of expansion and contraction with the main cables and the tie-downs.

And again, there's a laser system in the works that would measure the distance from all three corners of the platform to the

“Studying our galaxy is like being on a phonograph record and trying to find out where the grooves are”

ground and use a servomechanism to make tiny adjustments in the tie-downs. "We're shooting for a couple of millimeters, maybe one millimeter," said Merle Lalonde, a research associate at Cornell, who's working on the system.

That is much more impressive if you've actually seen the platform, a monster whose size can't really be grasped by looking at its pictures.

Numbers help a little. The platform is there to carry a circular track 130 feet in diameter, which is there to allow the free rotation of a feed arm, or azimuth, a bow-shaped, trussed structure. The azimuth, in turn, exists only to allow the observatory's reflector antennas to be moved into position. The antennas are mounted on two "carriage houses," or rooms; by rotating the azimuth and moving the carriage houses along the bow, the antennas can be aimed at any point in about 39 percent of the sky.

The azimuth is 304 feet long, slightly longer than a football field. The larger of the carriage houses has three rooms and would make a fairly comfortable dwelling for a small family. The largest antenna is 96 feet long and weighs five tons.

But I really got a feeling for all those numbers when someone told me that there were eight workers on the platform that day. By straining my eyes, I could just make them out. At that point, the sheer size of the observatory came home to me.

In radio astronomy—and about 60 percent of the observatory's time is spent in that work—the big dish not only has a sensitivity available nowhere else, but also a versatility that no other radio telescope can match. There are eight antennas, covering a wide range of frequencies (much wider since the dish was resurfaced), and each of them can be swung into position with unprecedented speed for observing an astronomical phenomenon.

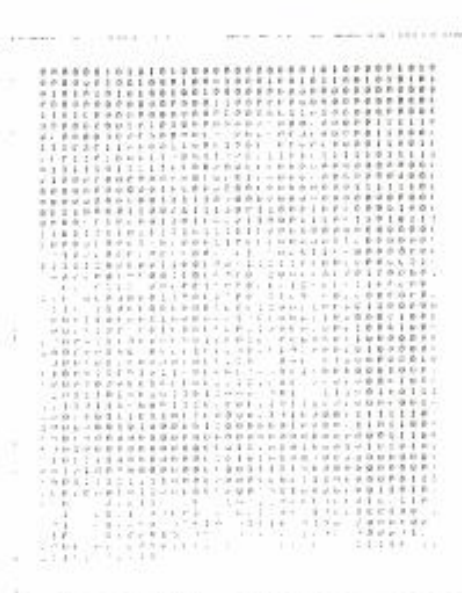
Edward Conklin, one of the radio astronomers at the observatory, explained that smaller radio telescopes just can't do that because an antenna apparatus of that size would effectively block their view of the sky. Smaller radio telescopes can mount only one antenna at a time, which limits them to studying a radio source at a single frequency. "We can look at a single object across the entire wavelength spectrum in a matter of hours," Conklin said.

The increased sensitivity and wavelength coverage of the improved telescope has radio astronomers making big plans. Conklin wants to use the new capabilities to try to make a better determination of the shape of our galaxy. Astronomers believe that the sun is in a spiral galaxy, he says, but the details are very fuzzy. Studying our galaxy, Conklin says, "is like being on a phonograph record and trying to find out where the grooves are." He'll try over the next few years, using the observatory's new ability to study the emissions given off by hydrogen in space.

Michael Davis, who shares an office with Conklin, said he will spend the next few years "testing models of the origin and evolution of the universe."

Many astrophysicists think that the universe began expanding in a "big bang" some 16 billion years ago. The question now is whether the expansion will continue forever or will reverse itself, and that depends on the amount of matter in the universe. So far, astronomers have been unable to find enough matter to provide the gravitational pull that would stop the expansion but there are hints that the

Arecibo's radio message to life in the galaxy



Mankind has listened briefly for messages from another civilization before—most notably in Project Ozma in 1960—but no conscious radio message to intelligent beings elsewhere was sent until 1:30 p.m. on November 16, 1974, during the rededication ceremony at the Arecibo Observatory.

Astronomer Frank D. Drake, who initiated the idea of the message and devised its form with members of the observatory staff, described it as "an anti-puzzle, a code designed to be broken easily."

The message was sent in the binary system, in which the only numerals are 0 and 1; in practice, the two numerals were represented by shifting between two radio frequencies. The whole message, as transmitted, is shown above.

There are 1679 characters in the message, a number chosen because it is divisible by 23 and 73, two prime numbers. It is assumed that any intelligent being who intercepts the message will lay out the units in 73 rows of 23 characters each, to give the picture shown at right. From then on, the picture is arranged to allow progressively complex interpretations.

At the top of the message, from right to left, are binary characters for the numbers from 1 to 10, sent in a complex form needed later in the message. Each number has an extra character, a "number label," added so that the interpreter can distinguish between numbers and other concepts in the message.

In addition, the symbols for the numbers 8, 9, and 10 have purposely been written in a complicated form, with extra digits to the left of the least significant digits, again so that the interpretation of larger numbers will be clear to whoever decodes the message.

Once the interpreter understands the number system, there is another key lesson in the group below—the symbols for the numbers 1, 6, 7, 8, and 15. These are the atomic numbers of five elements, hydrogen, carbon, nitrogen, oxygen and phosphorus, all essential to life on earth—and presumably elsewhere.

The 12 groups that follow on the next three lines are chemical formulas, giving the simplified structures of organic molecules containing the five elements described above. They include the phosphate group that plays an essential role in energy transfer in living cells; the sugar molecule, deoxyribose; and the molecules of thymine and guanine, and adenine and cytosine.

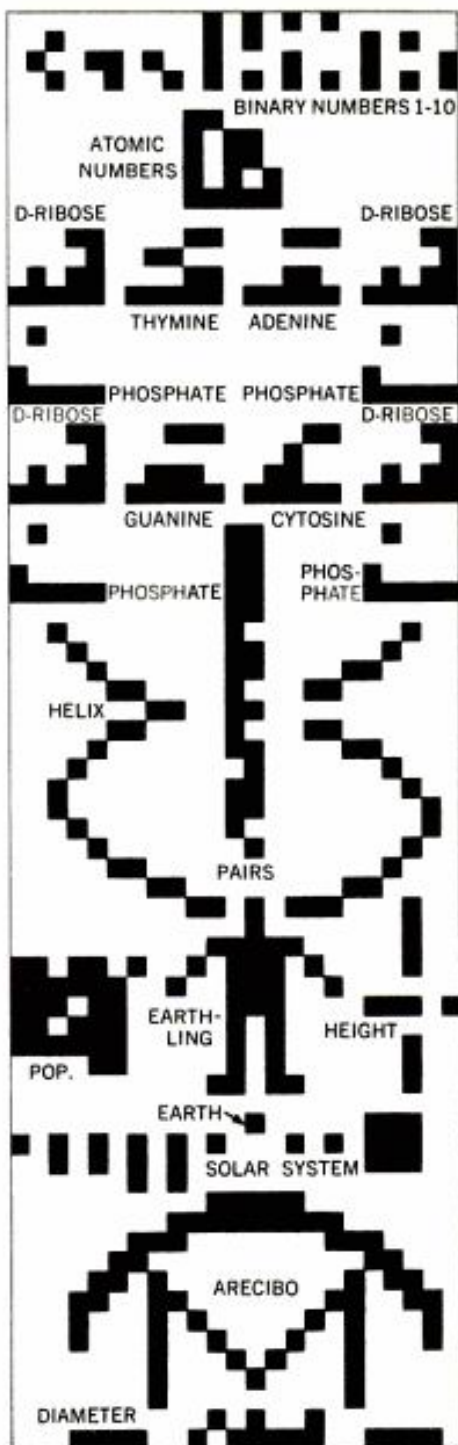
All these are constituents of deoxyribonucleic acid (DNA), the chemical that carries the genetic code; and the double helix in which these molecules exist in living cells is shown running down the middle of the message. In the center of the double helix is the binary notation for the number four billion, the number of subunits of DNA found in a typical human cell.

Below the DNA helix is a crude picture of a human; the line to the right, running from head to foot, is accompanied by the number 14. This denotes that the human is 14 units high. The decoder will understand, presumably, that the "unit" is 12.6 centimeters, the wavelength on which the message was transmitted, which would describe the figure as five feet 9½ inches tall. To the left of the figure is the number four billion, the human population of the planet.

Below the human figure is a rough sketch of the solar system, with the sun to the right and the nine planets arrayed to the left. The earth is slightly out of position, indicating that there is something unusual about this planet; the fact that the earth is displaced toward the human figure suggests that this is the home of the human.

Below the solar-system symbols is a crude picture of the Arecibo radio telescope, with binary numbers indicating its diameter as 1004 feet (slightly inaccurate, but easier to send).

The message was sent at the rate of



10 characters a second and took 169 seconds to transmit. It can be detected by a radio telescope the size of the Arecibo facility anywhere in our galaxy. The message was aimed at a globular cluster of stars called Messier 13. Estimated time of arrival: 26,974 A.D.

extra matter might be hiding somewhere. Davis is going to look for it.

There's a lot more than that going on in radio astronomy at Arecibo. The first night I walked into the observatory's control room I found Steve Spangler, a graduate student from the University of Iowa, doing an all-night study of "flare stars", an unusual species of red dwarfs that emit bursts of radio waves similar to those given off by

solar flares. Richard Isaacman, a Cornell graduate student, was going over data from a continuing study of the pulsar at the heart of the Crab Nebula. The value of Arecibo is attested to by the waiting time of several months that faces radio astronomers wanting to use the facility.

They'll have to stand aside for a time this summer to make way for the radar astronomers. With

Venus making a close approach to Earth, NASA has paid for installation of a 450-kilowatt radar transmitter, about as powerful as any now available, to make a radar map of that cloud-girdled planet. The Arecibo beam will reach across 25 million miles of space and clouds 35 miles thick to get images with a resolution of under a mile.

Because the radar beam, tight-

[Continued on page 132]

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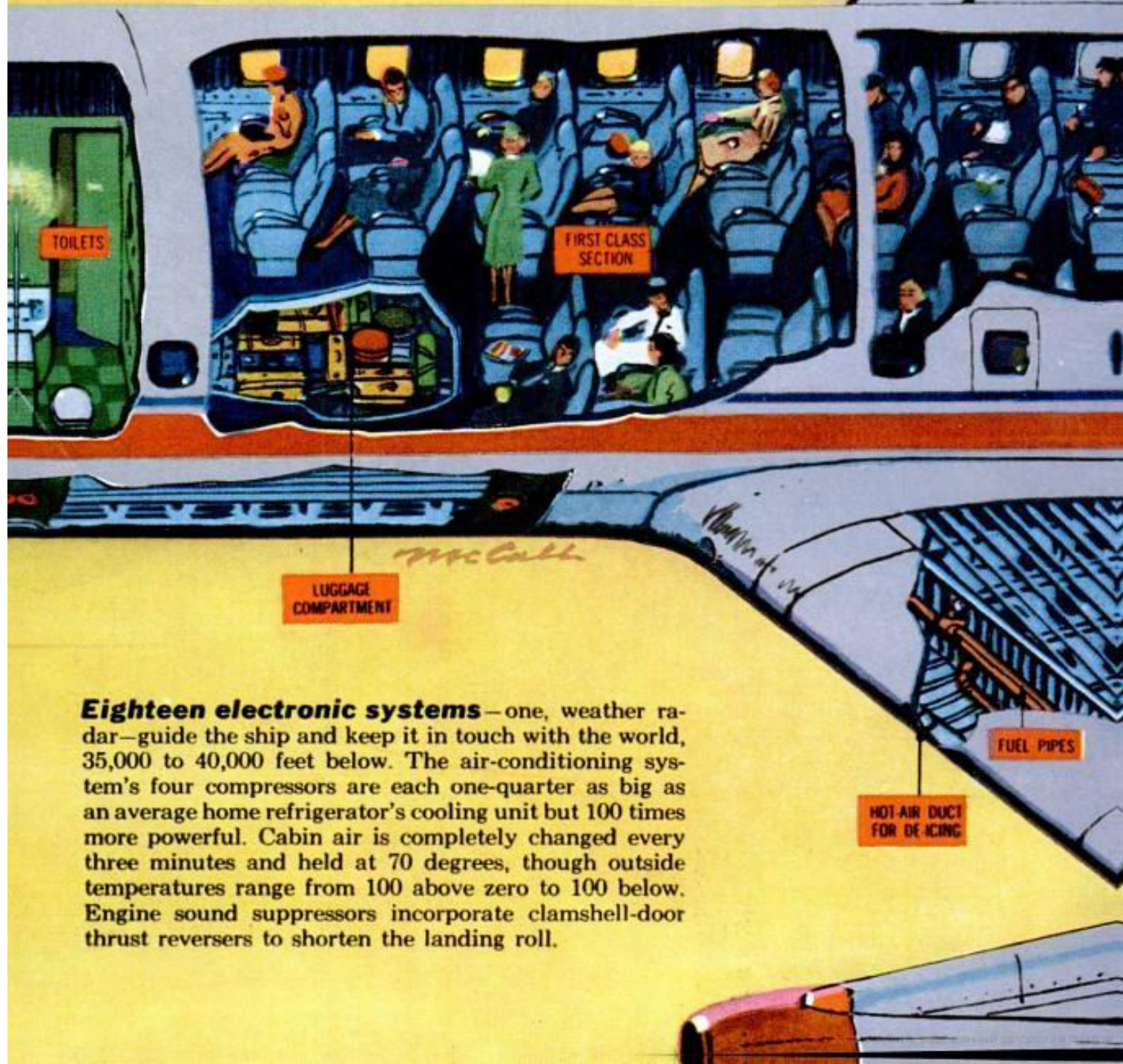
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PAGE 132

Huge DC-8, America's second jet transport,

Half a football field in length, the DC-8 stretches 150 feet, six inches from end to end and spreads its remarkably flexible, swept-back wings nearly as far: 139 feet, nine inches. The great hollow wings, whose elasticity cushions air turbulence as if they were giant springs, hold more than 57 tons (17,600 gallons) of kerosene, which is what jets burn. Yet they can be pressure-filled, from underneath, in 15 to 20 minutes.

The first DC-8s will have four P. & W. JT3 engines, driving them to 561 m.p.h. They make enough electricity for 60 homes.



starts service next fall. Four engines develop

TURN

LIFT SPOILERS
IN LANDING POSITION

LUGGAGE
COMPARTMENT

TOURIST
SECTION

FUEL

FLAPS

MAIN WHEELS
IN LANDING POSITION

24,000 hp. to lift 132-ton plane that can car



Chairs and bulkheads are on tracks, making it easy to vary the interior plan several ways, from the 119-passenger, mixed-class arrangement (above) chosen by United Air Lines for the first domestic DC-8 flights, to an all-tourist version seating 176. Each seat has a reading light, cold-air outlet, call button, aisle light, ash-tray, table and emergency oxygen outlet. A hi-fi system carries announcements and music to the quiet cabin, which is pressurized so that a sea-level atmosphere is maintained to 23,000 ft. At 34,000 ft., cabin pressure equals that of 5,000 ft.; at 40,000 ft., that of 6,700 ft. Two large compartments in the plane's belly hold nearly seven tons of luggage and cargo. Compartments are loaded from the star-board side while passengers use two port-side doors.

carry 176 people



The plane's soaring tail rises more than 42 feet above the ground. Hot air bled from the engines is circulated through ducts along the leading edges of wings, tail surfaces and engine pylons to prevent icing. Another thermal system keeps engine inlets, air-conditioning scoops and the radome ice-free. Blasts of hot air will clear the electrically heated windshields of rain and snow.

There are four wheels, mounted in tandem pairs, on each leg of the main landing gear. The rear pairs swivel, to make taxiing easier. Main wheels and nose wheels (two) will drop by gravity in case the hydraulic system fails.

The flight crew, with 120 instruments to watch, will contain a navigator only when the DC-8s start making ocean crossings.

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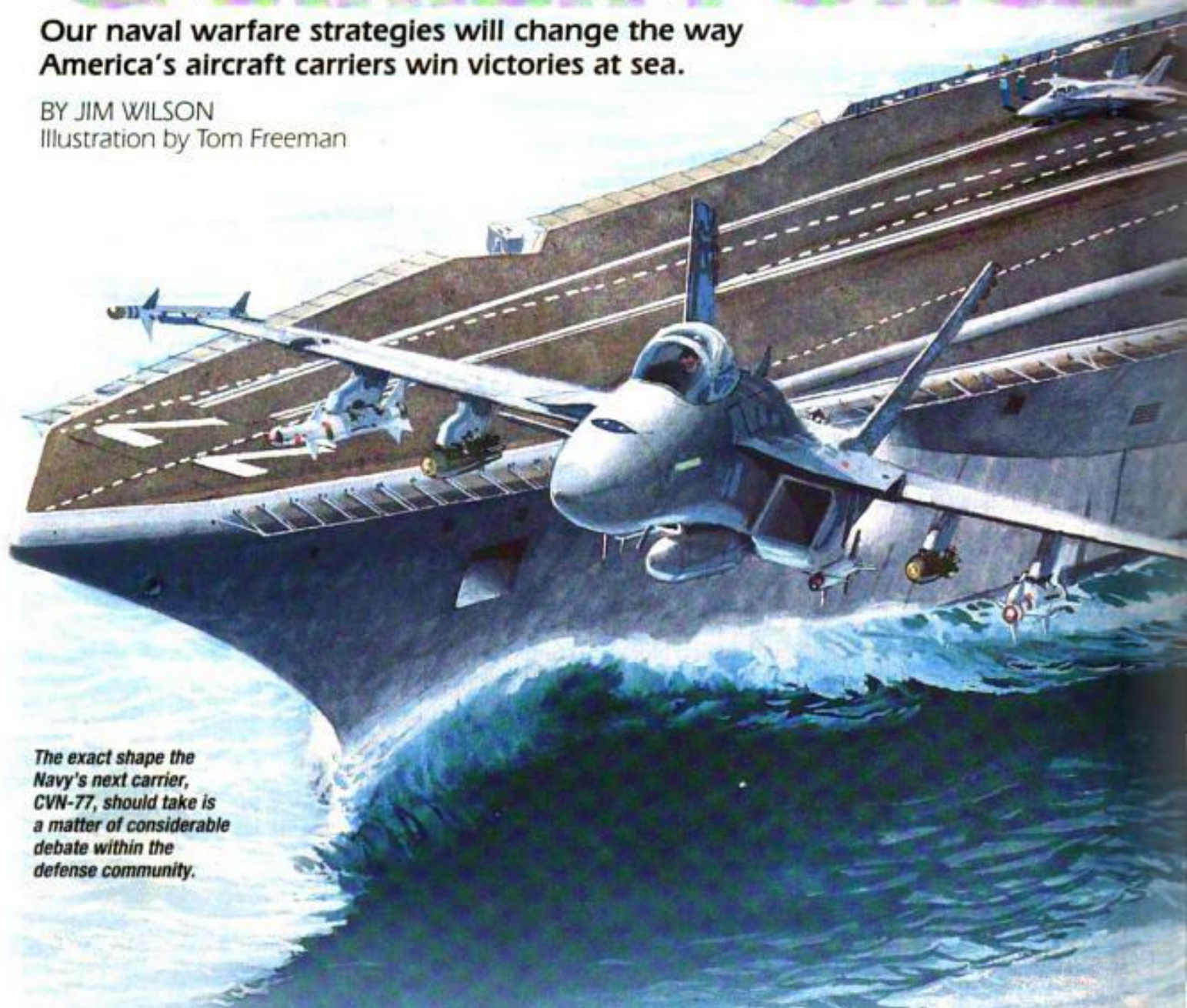


21ST CENTURY CARRIER FORCE

Our naval warfare strategies will change the way America's aircraft carriers win victories at sea.

BY JIM WILSON

Illustration by Tom Freeman



The exact shape the Navy's next carrier, CVN-77, should take is a matter of considerable debate within the defense community.

► It is a beautiful night on the

water. The Gulf of Mexico is as calm as a country lake and a wispy sea breeze gently stirs the moist tropical air. Stars bright as flashbulbs speckle the cloudless

COVER STORY

sky. All this tranquillity, though, is probably lost on the pilot of the fast-approaching jet. He is about to experience the most terrifying event of his young life, his first night landing on an aircraft carrier.

From our vantage point, on the landing safety officer's platform of the *USS John C. Stennis*, his plane seems to hang motionless. It is an optical illusion: In fact, 51,000 pounds of F-14 Tomcat are bearing down on us at 154 mph. Less than a heartbeat after we recognize the jet's distinctive twin-fins, its tailhook hits the deck about 50 ft. to our left. It throws off a shower of sparks that follows the plane like it's a grounded Roman candle. The rolling thunder of the jet's afterburners—an insurance policy that guarantees a speedy takeoff if the arresting cable breaks—crashes through the earplugs we're wearing.



would evolve to become the most powerful fighting machines afloat. Today, as the Navy prepares to build its last Nimitz-class carrier, the still-unnamed CVN-77, these awesome floating airports find themselves the target of the next explosive change in naval warfare.

The Last Nimitz

"CVN-77 is our transition carrier," says Rear Adm. David Putnam Sargent Jr., of the Naval Sea Systems Command in Arlington, Va. "Our objective is lowering the ownership costs of Nimitz-class [carriers] and at the same time to allow us to develop new technologies that can be used in the future." The carrier after CVN-77 currently exists as a research and development program, but it could be cast in steel before long. It is known by the code name CVX. The exact form that CVX takes will be shaped by two potentially conflicting forces: the practical lessons the Navy will learn in building CVN-77 and emerging naval strategies that reflect the new political realities of the post-Cold War era.

In 75 years of conducting air operations at sea the Navy has worked most of the bugs out of its carriers. One that persists, which the Navy hopes to avoid in CVN-77, has roused us from a sound sleep onboard the *Stennis*. The noise is so loud the ceiling of this state-room—PM ranks a lieutenant commander's quarters—could be the underside of a demolition site. The next morning the ship's executive officer explains that a crew spent the night servicing a jet-blast deflector located directly overhead.

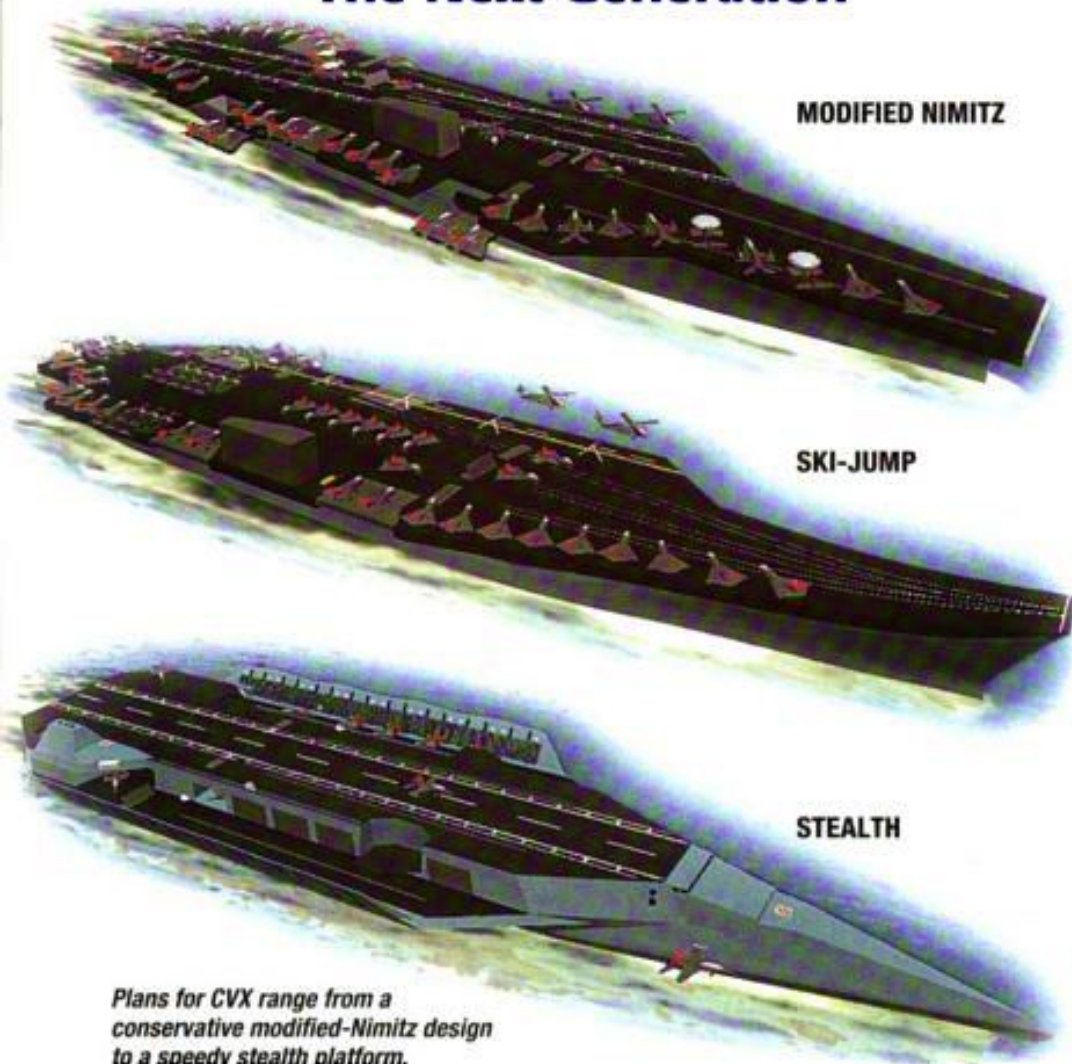
These large steel plates, one behind each of the carrier's four catapults, protect aircraft handlers from 2300° F jet exhaust. The plates are cooled with seawater,

The noise stops abruptly, signaling that the plane has come to a complete stop.

In the distance we can see a band of aircraft handlers rising from the shadows. They quickly inspect the plane and lock it into the nearby catapult. The same pilot spools up the twin engines. A sharp salute signals he is ready for takeoff. Enough high-pressure steam to fling a pickup truck $2\frac{1}{2}$ miles surges through the catapult's power cylinders. The pilot rockets into the night sky—and a new career as a naval aviator.

For more than half a century, the Navy's ability to launch and recover aircraft at sea has been the powerful swift sword of American foreign policy. The *Stennis* CVN-74, on which *POPULAR MECHANICS* has deployed, will carry this tradition forward far into the 21st century. One of eight operational Nimitz-class carriers, she traces her heritage and basic "flattop" design back more than 75 years to when the collier *Jupiter* was topped with a wooden flight deck and rechristened as the Navy's first aircraft carrier, the *Langley* (see "Navy Building Battleship Of New Design," March 1921, page 331). Born in an era when nations projected their wills from the barrels of big guns atop battleships, flattops

The Next Generation



Plans for CVX range from a conservative modified-Nimitz design to a speedy stealth platform.

which is plentiful but also corrosive. "It has been a maintenance headache on all carriers," Richard R. Doerner, design manager at Newport News Shipbuilding's Carrier Innovation Center in Newport News, Va., later tells PM. When CVN-77 puts to sea in 2008, the metal deflectors will probably be replaced with a passive heat shield to eliminate the need for seawater and its attendant maintenance problems.

Smaller Crews

This may seem like a small modification, but the Navy sees such steps as essential to making a 12-carrier fleet affordable. On average, a Nimitz-class carrier costs about \$4 billion to build and \$2 billion a year to operate, according to the General Accounting Office. The 80 or so planes are extra. And the fact that they become obsolete faster than the ships adds substantially to total costs. The F/A-18E/F program to equip carriers with the next generation of aircraft comes with an \$81 billion price tag. Add to this the cost of the scores of ships needed to ser-

vice and protect carrier battle groups and you get a sense of the cost problem. "Some members [of Congress] believe that alternatives to the Nimitz design offer a more cost-effective means of basing aircraft at sea," says defense analyst Scott C. Truver.

Following the lead of industries that have successfully used automation to reduce the size of workforces, the Navy is looking to downsize the 5000-man crews of Nimitz-class ships. Although it hasn't set precise numbers for the size of future crews, one hint of the Navy's long-term goal comes from its enthusiasm about an automated bomb-handling system that will let one sailor do work now handled by nine.

Some changes will be more obvious than others. As a Nimitz-class carrier, CVN-77 will have the same below-deck structure as her sister ships, right down to twin nuclear reactors (see "Show Of Force," March 1990, page 49). Above the flight deck the change that will most visibly set her apart will be the replacement of her island—a multistory structure re-

sembling an airport control tower—with two low, squat control centers.

On flattops the island typically houses the helm and navigation centers, as well as observation suites for the carrier air group commander, captain and, from time to time, the admiral responsible for the battle group. From the observation areas, the views of the flight deck and ocean are spectacular. Unfortunately, the radar return that bounces off these towers makes a carrier stand out like the proverbial sore thumb. Current plans for CVN-77 call for replacing the broad expanses of windows with broad expanses of display screens that will show satellite and combat-radar imagery. The change will make it possible to reduce the single, tall island to two small structures shaped to scatter rather than reflect signals transmitted by enemy radar.

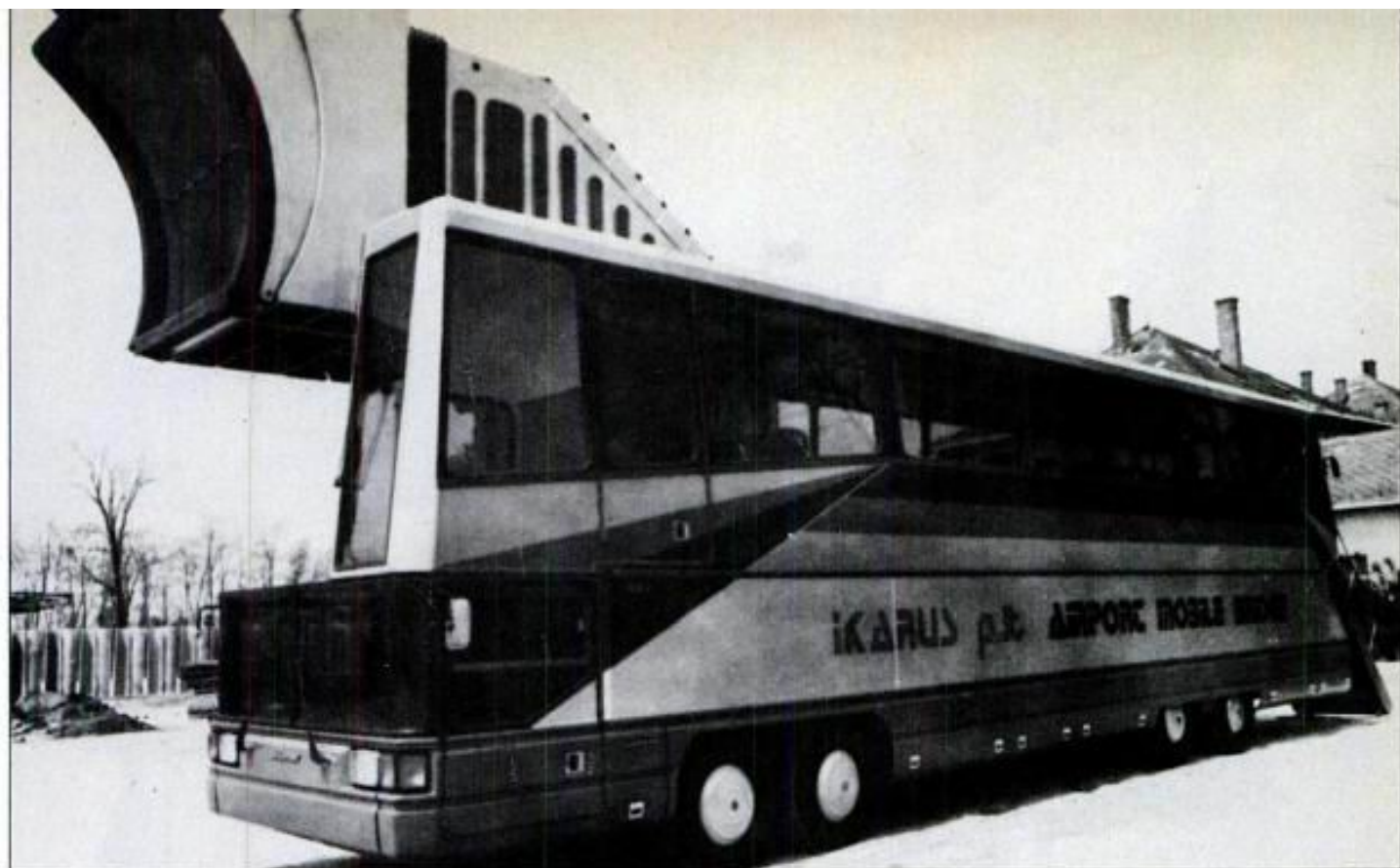
Whatever the eventual crew size and deck configuration of CVN-77, defense analysts believe one thing is almost certain: She is likely to be the last of the large flattops. However, this downsizing isn't the Navy's idea, but the enemy's.

New Enemies

"When the steel for CVX is poured in 2006, the final shape will represent almost 80 years of carrier development," says Capt. Mark O'Hare, the Navy's carrier program manager. The overall shape of the flattop carrier was cast during the Second World War. Changes made to carriers during the Cold War era stemmed mainly from the switch from oil to nuclear fuel and the need to fine-tune weapons systems to keep ahead of the Soviet navy.

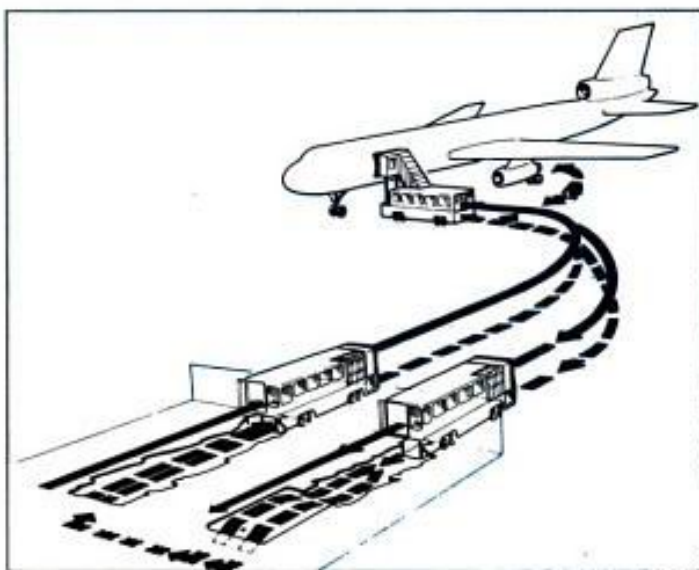
After preparing for so long to engage the Soviet Union on the deep blue waters of the open seas, naval aviation planners now find themselves facing a totally unexpected turn of events. "With the Soviet Union's collapse in 1991 there is simply no blue-water enemy to sink," says Andrew F. Krepinevich Jr., of the Center for Strategic and Budgetary Assessments, a Washington, D.C.-based think tank that analyzes defense strategies.

Krepinevich and some other military analysts see this lull in hostili-



Door-to-door service aboard this *airport bus*

A new bus, with a driver's position at each end, a built-in elevating stairway, and automatic baggage-handling equipment, will cut down on long walks, add to passenger convenience, and reduce airport-building costs. Prototype units are being tested in Europe.



By DAVID SCOTT

BUDAPEST, HUNGARY

One of the worst parts of flying is the long walk through an airport to your gate. And if this isn't irksome enough, there's always the walk at the end of the flight and the inevitable wait for your checked baggage.

But now a Hungarian company has devised a shortcut for foot-sore travelers. It's a bus called Aeropalt, for (Aero) Passengers and Luggage Together. Here's how it works: Check-in is at the departure door—the bus designated for your flight is waiting just outside the door. You drop your suitcase onto a pallet, place carry-on bags on an X-ray machine conveyor, and step through a metal detector.

The bus is docked end-on against the building, and you step aboard through its rear door. As each luggage pallet is filled, it's conveyed forward and down into the lower level of the bus. There, it's transferred to an under-floor conveyor running the length of the vehicle's body.

When the bus is fully loaded, the driver takes you to the aircraft, stopping just beneath the passenger door. He pushes a button, and a flight of stairs rises from one side of the forward third of the bus's main floor. You walk up the steps into the plane and take your seat. At the same time, the conveyor below discharges the baggage pallets out of the back of the bus onto an elevating loader truck.

At your destination the sequence is

reversed. The bus is bidirectional, with a driver's compartment at each end, so the shuttle is speedy.

Aeropalt Ltd., a new Hungarian company created to promote this idea, cites several advantages of the system, aside from passenger convenience. Because baggage for a given flight stays with its owners, there's little risk of pilferage or of misdirected or lost bags. Terminal buildings could be smaller and less costly, with shorter causeways.

Prototype vehicles have been built in Hungary by Ikarus, Europe's largest bus manufacturer. Another version planned by Ikarus is a road vehicle plying directly between a center-city air terminal and parked aircraft. It would bypass the airport buildings entirely.

13

Coming: an orbiting research center — **Spacelab**

European modules mate with American shuttle to put science in orbit

By **JIM SCHEFTER**

ILLUSTRATION BY RAY PIOCH

After three awesome flights, the excitement is fading and the space shuttle is getting ready to do its real work. Late next year, when the orbiter yawns wide its payload doors in orbit, it will expose a cargo hold crammed full from rear cabin bulkhead to engine pods. A 23-foot cylinder will dominate, sandwiched between an elbowed tube and a large pallet loaded with instruments.

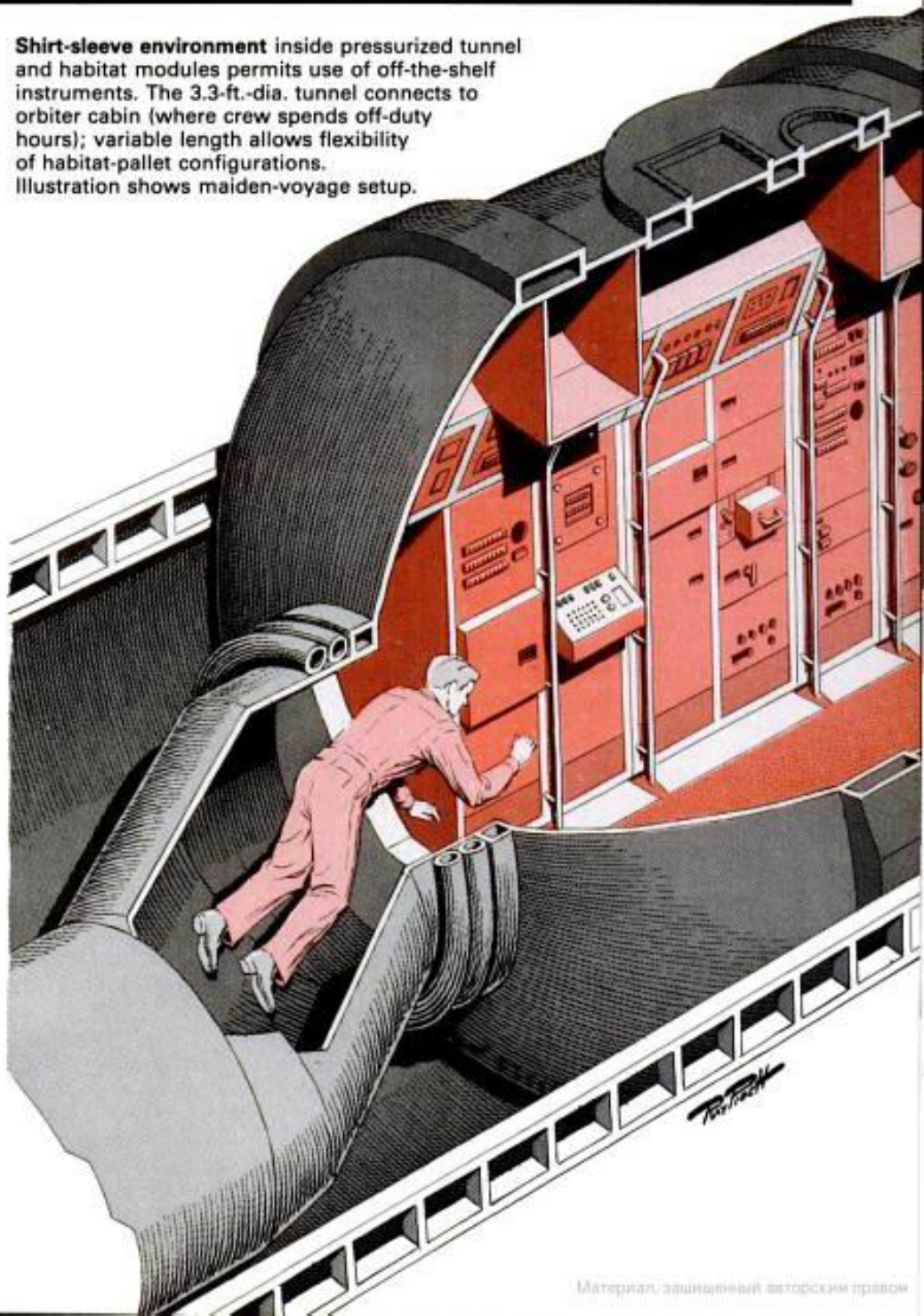
This is Spacelab—a versatile and expandable system of manned and unmanned hardware that will put a true scientific laboratory and non-astronaut scientists into orbit for a week at a time.

Spacelab is smaller than NASA's first orbiting research station, Skylab. But Skylab had a limited life; Spacelab is ultimately more usable and reusable. For the western world it is the next step toward establishing a permanent, manned presence in space.

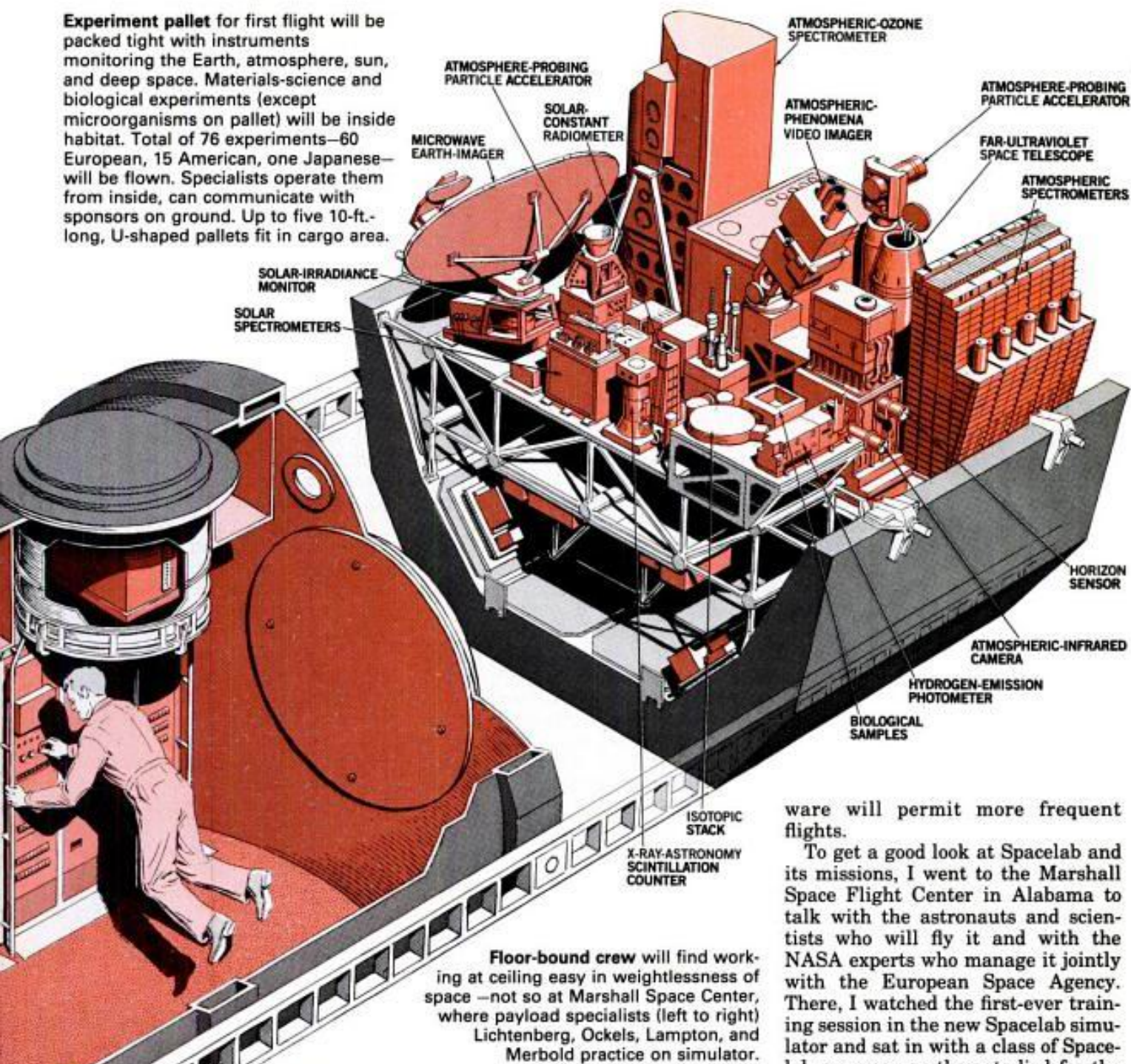
"The Russians are already there," a concerned NASA official told me. "They not only beat us with their Salyut station, but they've already exhausted its capabilities. They're building toward the next level of space station. We just don't know when it will fly."

Spacelab will fly with its six-person crew—including the first non-American to go into space aboard a U.S. craft—in September 1983. Four more missions are to follow in 1984 and 1985. After that, a second set of hard-

Shirt-sleeve environment inside pressurized tunnel and habitat modules permits use of off-the-shelf instruments. The 3.3-ft.-dia. tunnel connects to orbiter cabin (where crew spends off-duty hours); variable length allows flexibility of habitat-pallet configurations. Illustration shows maiden-voyage setup.



Experiment pallet for first flight will be packed tight with instruments monitoring the Earth, atmosphere, sun, and deep space. Materials-science and biological experiments (except microorganisms on pallet) will be inside habitat. Total of 76 experiments—60 European, 15 American, one Japanese—will be flown. Specialists operate them from inside, can communicate with sponsors on ground. Up to five 10-ft.-long, U-shaped pallets fit in cargo area.



Floor-bound crew will find working at ceiling easy in weightlessness of space—not so at Marshall Space Center, where payload specialists (left to right) Lichtenberg, Ockels, Lampton, and Merbold practice on simulator.



ware will permit more frequent flights.

To get a good look at Spacelab and its missions, I went to the Marshall Space Flight Center in Alabama to talk with the astronauts and scientists who will fly it and with the NASA experts who manage it jointly with the European Space Agency. There, I watched the first-ever training session in the new Spacelab simulator and sat in with a class of Spacelab crewmen as they studied for the upcoming flight.

"Spacelab is as much like a science laboratory on Earth as possible," mission manager Harry Craft told me. "It has a 14.7-psi internal pressure, an atmospheric mix of 80-20 nitrogen and oxygen, standard 19-inch equipment racks, easy access to power plugs, and even a workbench where the crew can work on instruments."

The Spacelab program grew out of studies in the late 1960's overseen by Wernher von Braun. Originally conceived as a "sortie module" that could be carried into space, left for a time, and retrieved, it nearly fell victim to declining budgets. But growing European interest in exploiting space led to a unique international agreement.

The European Space Agency and

Continued



You'll never miss a ball game with **go-anywhere TV**

Small-screen sets, diminutive in size and versatile in power requirements, let you take your show on the road

By **V. ELAINE SMAY**
PHOTO BY GREG SHARKO

What do you do when:

- It's time for the opening kickoff of the Superbowl and you're stuck in traffic?
- You're two-thirds through "Gone with the Wind" and the power goes off?
- You want to use your new Timex Sinclair portable computer [PS, Aug.] on a business trip, but you need a television set to serve as a display?

Answer: You reach for your portable TV. And I don't mean some 40-pound colossus that happens to have a handle on top. Today you can get a TV that's almost as easy to take along as a tape recorder. Smallest to date, Sony's monochrome Watchman (see photo) will slip into a roomy pocket or ride in a briefcase—with lots of room to spare. Probably the smallest color set, Panasonic's CT-3311 (not

available when we took our picture) has a 2.6-inch screen and a cabinet about the size of a child's shoe box.

If you're willing to sacrifice some compactness, you can get a unit that includes a radio, tape recorder, and perhaps a clock along with the TV. One even includes a micro video cassette recorder.

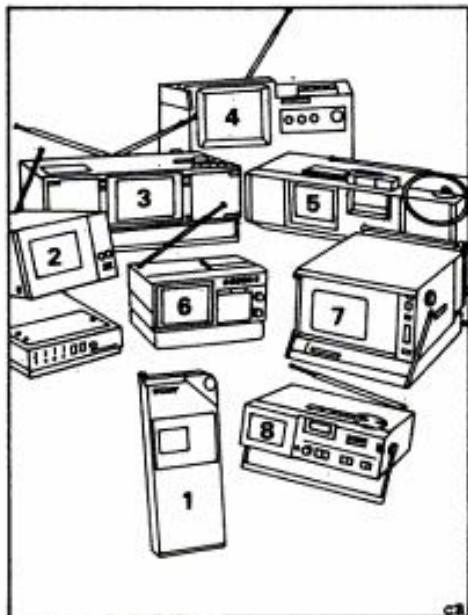
These little TV's can get their power from a variety of sources. Most can run on either line current, batteries (dry cells or rechargeables), or a car battery.

Flattening the screen

Sony's Watchman is the first TV on the market with a flat display. Like the others, it uses an electron-gun phosphor-screen cathode-ray tube (CRT). But Sony has put the electron gun below the phosphor screen and parallel to it (rather than behind and perpendicular to it), forming a paddle-shaped CRT that's only $\frac{3}{8}$ inch thick.

Sinclair Research Ltd. is about to bring out its own monochrome TV with a flat CRT [PS, June '81]. It will include an FM radio and sell for less than \$100.

Seiko, the Japanese watch company, has taken another route to flat-screen TV. Due on the market soon is its wristwatch TV with a liquid-crystal screen [see "What's New," this issue]. Sorry about that, Dick Tracy. **■**



- 1) Sony FD-210, the Watchman, a monochrome TV with two-inch screen, measures eight by 3½ by 1¼ inches, weighs just over a pound. Price: \$350.
- 2) Sony's Trinitron color TV, the KV-4100, has a 3.7-inch screen. Push a button and the TV section lifts to reveal an AM/FM radio and microcassette recorder (with memory). Input-output jacks allow hookup to VCR or video camera. Price: \$880.
- 3) JVC CX-710 has a five-inch color TV, AM/FM stereo radio, stereo cassette-tape recorder, jacks for external speakers, mikes, headphones. Size: 16 by 11½ by 4½ inches. Price: \$720.
- 4) Technicolor Video Showcase combines a 7½-inch color TV with a portable microvideo cassette recorder (¼-inch tapes). You can shoot with any video camera and have instant replay. It weighs 24 pounds, measures 18½ by 12¾ by 7¾, costs \$1,795, with rechargeable battery.
- 5) General Electric's Road Show features a four-inch color TV, AM/FM

FM stereo radio, a detachable stereo microcassette-tape recorder, and stereo headphones. Price of the model 4CM3326X: around \$700.
- 6) Panasonic's Outsider line includes this four-inch monochrome TV, model TR-4030P, with electronic push-button tuning. Detachable battery case (shown under set), with 10 D cells, adds about five pounds to the basic three-pound weight, and is included in the \$200 price.
- 7) Toshiba's CA-045 color TV has a 4½-inch screen, pull-out sunshade, jacks for VCR or video camera. Size: 10½ by 7¾ by 4½; price: \$500. Optional battery case (under set) takes nine D cells or rechargeable nicad.
- 8) Sanyo TPM 1100 is a monochrome two-inch TV, AM/FM radio, LCD quartz alarm clock. The set comes with a vinyl carrying case and shoulder strap. Detachable hood for TV improves outdoor viewing; magnifying lens is optional. Size: 6¾ by 6¾ by 2½; weight: about three pounds (with six AA cells). Price: \$250.

Hand-size, but here at last: **flat-screen color TV**

Pocket-size TV sets using a flat screen and liquid-crystal displays are already in the stores. But they have monochrome (single-color) displays. Now, breakthroughs by a team of Seiko engineers in liquid-crystal chemistry and transistor design are finally going to

bring flat-screen color TV to the marketplace. The Japanese engineers have created new fast-response liquid crystals and thin-film transistors that overcome the major problems of LCD color TV. The Seiko Pocket Color TV should be on the market in about six months. A PS editor

visited Seiko's research and development headquarters in Suwa, Japan. He found picture quality highly satisfactory. Although the colors were not as crisp as the very best produced by cathode-ray tubes, they were bright in daylight, and resolution was sharp and clear.

By HERBERT SHULDINER

SUWA, JAPAN

The image was clear and the colors were bright as I watched a baseball game on the tiny screen of a TV set small enough to slip into my jacket pocket. But the fact that the athletes were Japanese wasn't the only thing different about this TV picture. I was viewing the world's first flat-screen liquid-crystal color television announced for sale.

LCDs aren't new, of course. Many of us have calculators or watches with the displays. And black-and-white LCD TV sets are already on the market, including a tiny wrist-watch TV [PS, April]. So why all the excitement about this new system? And why have a handful of Japanese companies, including Hitachi, Matsushita (Panasonic), Seiko, and Toshiba been in a race to be first to market this type of TV? Each one of the companies has demonstrated prototypes at electronics trade shows. In addition, Mitsubishi has exhibited a large-screen LCD color TV designed for industrial displays. Now Seiko has announced plans to market the first consumer LCD color TV. It will be on the market in about six months.

The Seiko TV is a prodigious engineering achievement. A color LCD TV is much more difficult to make than a black-and-white one. The Seiko Pocket Color TV required the use of a new type of liquid crystal, which responds twice as fast as conventional LCs, and virtually invisible thin-film field-effect transistors. The use of thin-film transistors had been limited to exotic flat-screen displays made for the military.

I visited the Seiko research and development center in Suwa to preview the new color-TV system. I also interviewed the three engineers who headed a 20-man research team that developed the system over a period of approximately five years.

"The principle is very simple," Toshiaki Saito, director of Seiko's research and development division, told me as he held the 1.1-pound TV set in his hand. "The system is much the same as that used in an LCD watch," he continued. "Liquid crystals are sandwiched between two panels of glass.

When the LC spots are excited by a voltage, the spots turn black, just as they do in an electronic watch."

But there are significant differences between a watch and the color-TV set, Saito says. Besides the new LCs and thin-film transistors, a color filter is used to create an entire spectrum of hues for the TV image.

Twisted crystals

The new liquid crystals used in the Pocket TV resulted, Saito says, from organic-chemistry research carried on by Seiko. But he refused to specify how they differ chemically. "We use twisted-nematic-mode LCs [see drawing on last page of article] because they have high contrast and low power consumption, and they respond in less than half the time of conventional LCs—less than 50 milliseconds compared with about 100 milliseconds." The rodlike, twisted-nematic-mode LCs are used in virtually all calculator and electronic watch displays made today.

Shinji Morozumi, manager of Seiko's research and development department, explained why LC response speed is critical in a TV set: "When you see a baseball game on a screen made of conventional liquid crystals, the image flows. A thrown or batted ball looks like a comet." There was no indication of this, however, as I watched the videotaped ball game on the Pocket TV screen. I could see the ball clearly, and when players ran they could be seen distinctly, without any blurring. To make sure this wasn't due to the fact that I was watching a specially selected tape, I asked Morozumi to tune in a real-time broadcast. He immediately disconnected the VCR cable and extended the set's telescoping antenna. He handed me the little TV, and I tuned in a Japanese soap opera. The colors were still bright, and moving images remained stable. There was no blurring whatever.

The LCs in the Seiko Pocket TV are encased in a 43.2-mm-by-34.2-mm (1.7-by-1.3-in.) glass-sandwich panel (see illustration on opposite page), which is divided into 57,600 pixels, or picture elements. Driving each pixel, Morozumi explains, is a matching thin-film transistor. The transistors, made in a Seiko integrated-circuit plant near here, are virtually invisible, as I found when I examined a screen panel not

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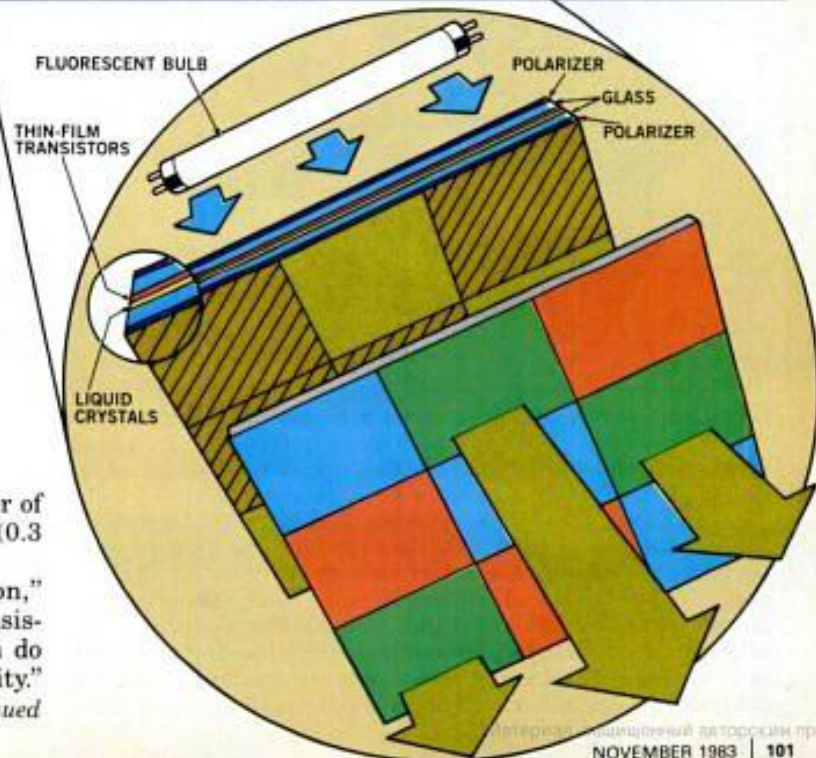


Heart of Seiko's new Pocket Color TV is the panel shown above. It's a sandwich encasing liquid crystals and a vast array of thin-film—virtually invisible—transistors. Liquid crystals form 57,600 matching pixels, or picture elements. Combinations of primary red, blue, and green elements form different colors. The exploded drawing at right shows how the green color on the screen is created. Varying voltages can change pixels from black to transparent. Black pixels (red and blue in diagram) block light; transparent ones allow light to pass and hit color filter. When the voltage is off, the green pixels are transparent; they allow light to pass and strike green elements on color filter. The result is green color on the screen. By turning voltage on and off in various combinations of primary colors, the overall color picture on screen is obtained.

enclosed in a case. The transistors are made on a layer of polycrystalline silicon only about 3,000 angstroms (0.3 micron) thick.

"We made the transistors of polycrystalline silicon," Morozumi said, "because conventional thin-film transistors made of cadmium selenide or amorphous silicon do not have sufficient stability, reproducibility, or reliability."

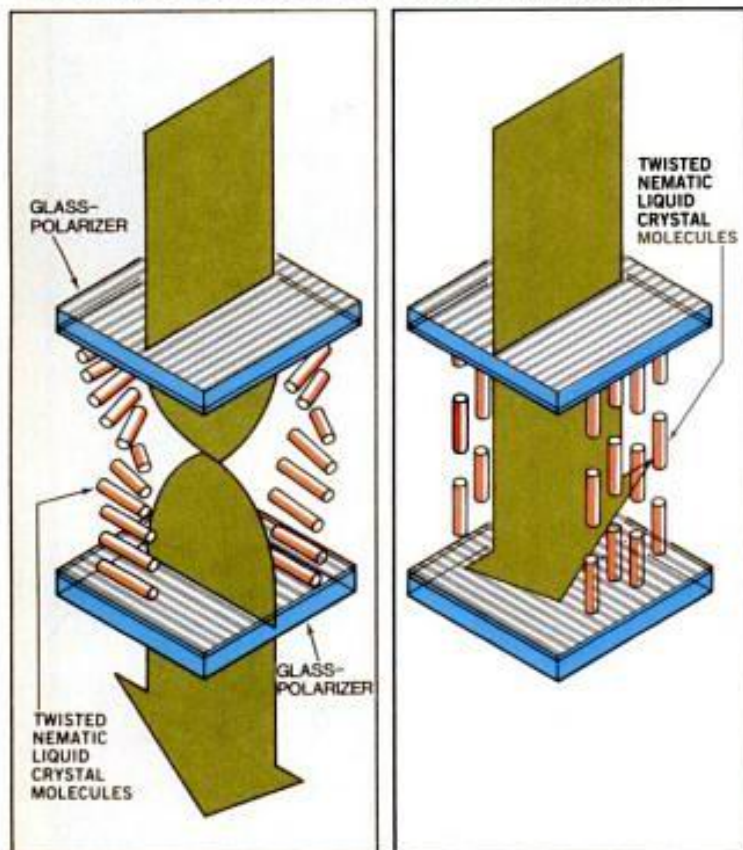
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Tiny Seiko TV is slightly more than one in. thick. Measurements of the prototype are 6.3 by 3.15 by 1.1 in. It weighs 17.6 oz. Playing time is four hours on four AA alkalines.

How LCs are used to make a TV picture



New fast-response, twisted-nematic liquid crystals are sandwiched between glass light polarizers in the color-TV panel and activated by adjacent thin-film transistors. When an individual pixel is off, with no voltage applied (left), light passing through the first polarizer is twisted 90 degrees by the liquid-crystal material. This enables the light to pass through the second polarizer (which is oriented at right angles to the first) and to strike a color filter. When voltage is applied to the LC cell (right), the rodlike molecules are aligned. As a result, light passing through the first polarizer is no longer twisted 90 degrees and is blocked by the second polarizer layer. LCs in watches work in much the same way.

Additionally, polycrystalline silicon transistors have high contrast. "A conventional LCD does not have sufficient contrast," Morozumi said.

Overall, the picture on Seiko's tiny screen is adequate once you get used to squinting at such a small image. Close-ups, as in soap operas, are easier to view than distant shots. The colors, though not as bright and crisp as those on a conventional cathode-ray tube, are more than adequate. The reds seemed especially good.

Compared with the Sony Watchman [PS, Nov. '82], the Pocket TV's picture is more pleasing because of the color. Resolution appears to be about the same, even though the Watchman is a flattened CRT and not an LCD. Seiko claims the resolution of its Pocket TV is about 200 horizontal lines (seven lines per millimeter).

The Pocket TV picture is more easily viewed than that of the wristwatch TV that Seiko also makes. I haven't had an opportunity to view either the Casio LCD black-and-white TV that went on sale recently or the EXP Research shirt-pocket LCD TV ["What's New in Electronics," PS, Aug.] scheduled to go on sale shortly.

The Casio LCD screen is slightly larger than that of the Seiko Pocket Color TV—2.75 inches versus 2.13. Screen size of the EXP model is only 1.5 inches. The Casio unit has a backlight made of electroluminescent materials instead of the fluorescent tube used in the Seiko. The backlight is needed to provide uniform illumination during the day and for night viewing. Liquid crystals merely reflect light, and when the viewing area is dark the display cannot be seen without a backlight.

Plummeting prices

Sony started the pocket TV era with its Watchman, just as it launched the tiny-portable-stereo era with the Walkman. The Watchman is certain to get considerable competition from the Casio model, which is bound to drive prices down. The Watchman lists at \$350; Casio has announced a price of \$299 for the TV-10. EXP Research will price its unit at \$275. The Seiko TV wristwatch sells for \$495.

Seiko's Saito says the Pocket Color TV will be priced at between \$400 and \$500 when it goes on sale in mid-1984. Who will buy that kind of device for that kind of money? "We expect it to be a popular gift item," Saito said.

Many industry observers believe, however, that LCD TVs represent more than just another fad potential. There's considerable speculation about whether these small models could eventually lead to an enlarged flat-screen television you could hang on the wall. I asked Saito whether Seiko plans to build a new generation of LCD hang-on-the-wall televisions.

"Right now, we could build a five- or six-inch flat-screen TV," he told me. But he admits that the company hasn't yet done so. The reason? "It would be extremely expensive to do and would not be competitive with other types of TV," he explained. What about eventually building a large-size flat-screen TV with pocket-TV technology? "We could build a 12-inch screen for alphanumeric display at this time," Saito said. "You don't need the response speed for an alphanumeric display. But it is quite difficult to achieve a hang-on-the-wall television using this kind of technology." As he thought more about it, Saito admitted: "It would be almost impossible to fabricate thin-film transistors on such a large area. Projection TV is an easier way to achieve a hang-on-the-wall TV."

At the same time, however, Saito told me: "We have yet another way to achieve the large screen area. It uses an altogether different technology, but I can't tell you about it now," he said teasingly. "Perhaps it will take five years—or even more—to achieve this large-area television."

The WHAT'S NEW magazine

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Here at last:

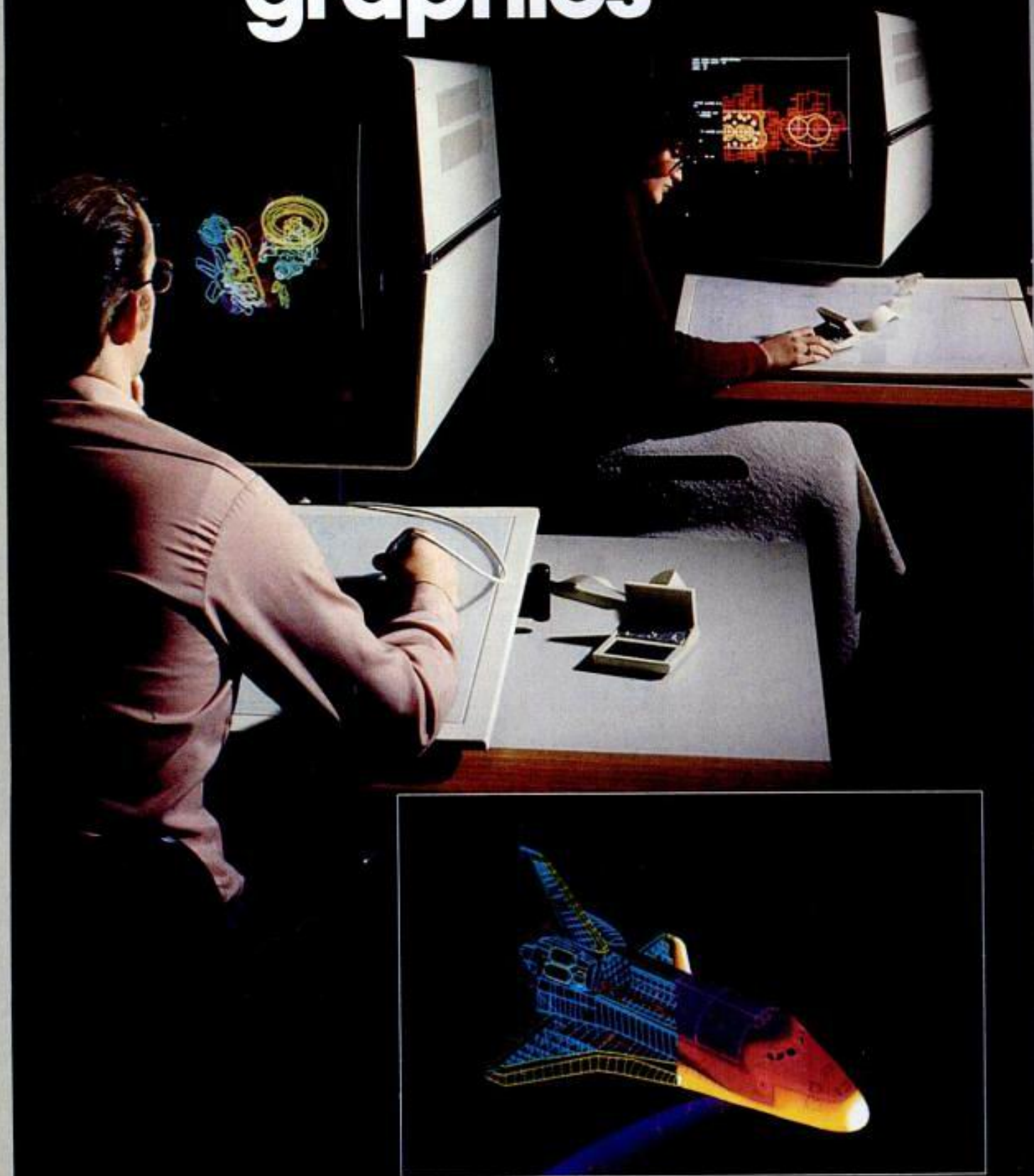
Flat-screen color TV



Spy photos from space



The creativity explosion in
**computer
graphics**



Cheaper memories, new VLSI graphics chips, true 3-D displays, and new software trigger a boom

By JOHN FREE

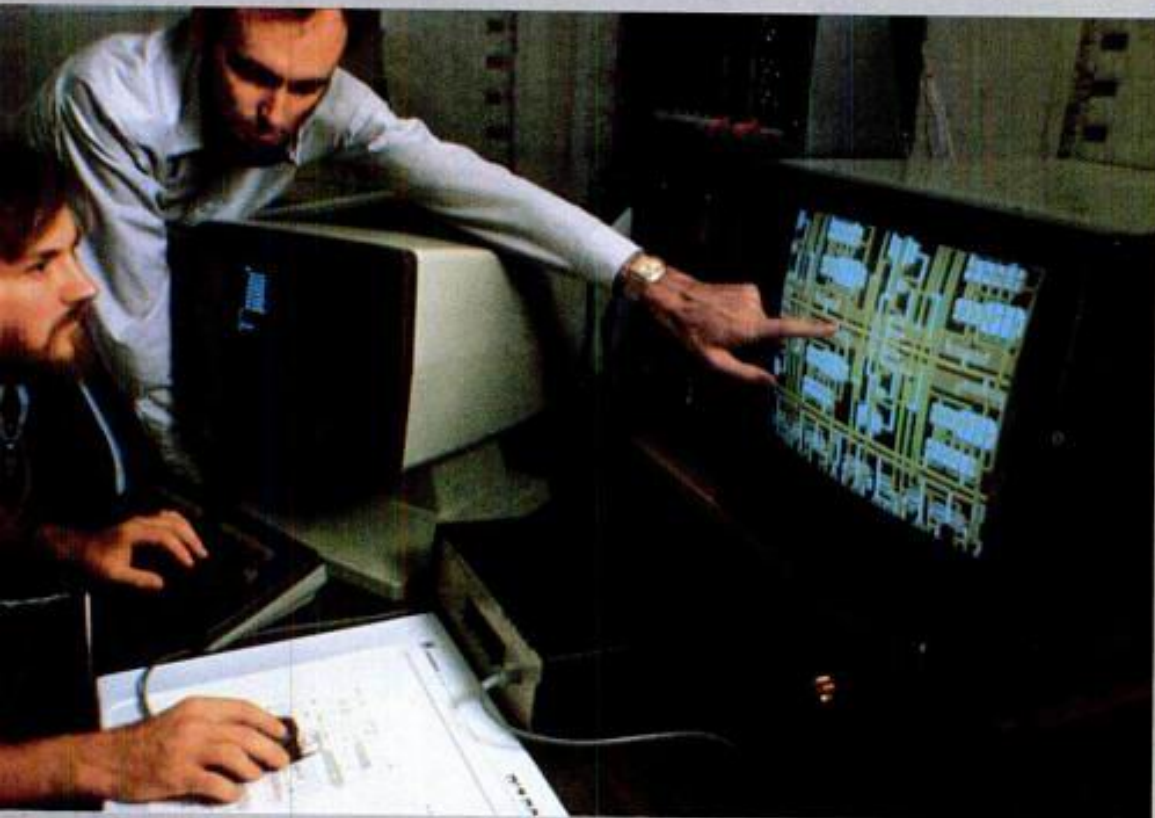
In Walt Disney's "Tron," a fantasy making its premier in July, a young computer genius named Flynn (Jeff Bridges) breaks into ENCOM, a futuristic computer complex. Suddenly he's detected and zapped into another dimension—an electronic microcivilization within ENCOM.

"Tron" is a Hollywood first. A third of its action occurs on nonexistent "sets"—images put on film by computers. Moviegoers are swept into an eerie world where landscapes, buildings, and vehicles have been created on TV-like computer-graphics terminals.

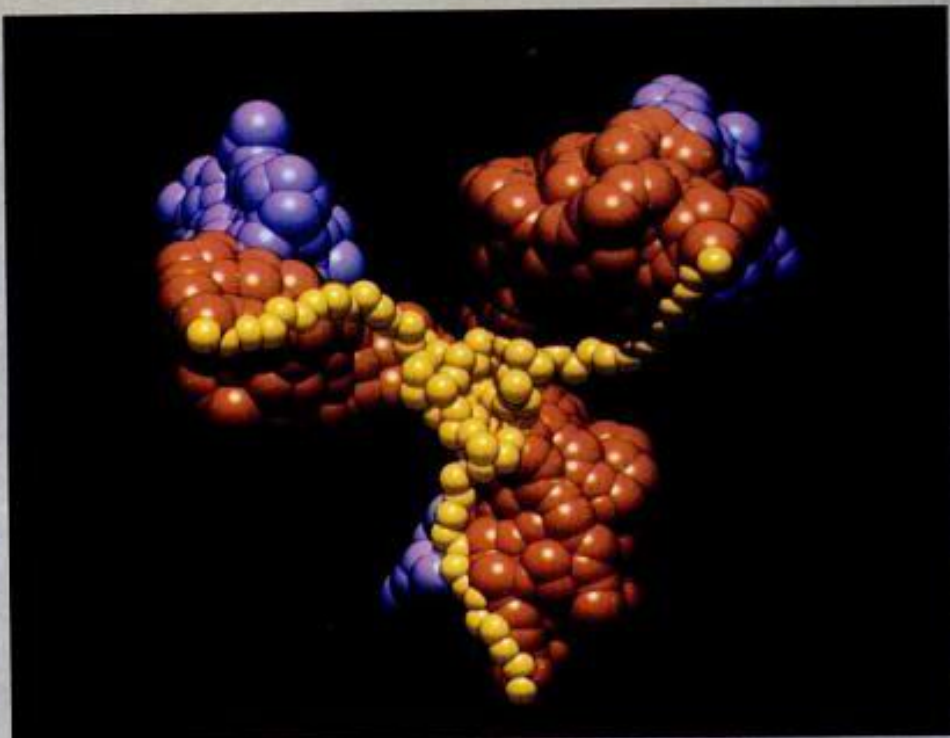
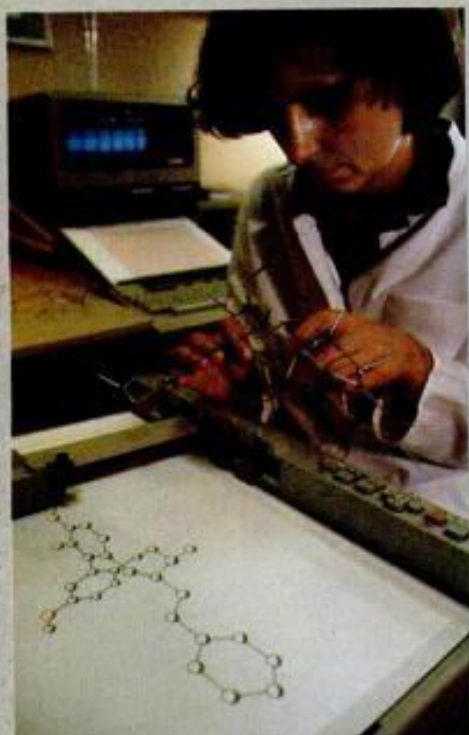
Steep costs once limited these terminals to specialists in big corporations and other institutions. But new developments are making graphics terminals available to artists, students, business people, architects, engineers, and many others at relatively modest prices. This wider access to computers that draw pictures has brought about an explosion of creative new uses.

The new advances are built on several key developments. For example, powerful new programming—software—written for graphics is becoming

Continued



Colorful displays on Computervision terminals (facing page) give designers a powerful method for interacting with computers tied to the work stations. Wire-frame engine components displayed are quickly created and manipulated on the screen. Solid surfaces, such as the glowing space shuttle (inset), require more sophisticated software and greater computing time. The shuttle image, captured with a Dunn Instruments camera, was made on a Hewlett-Packard desk-top computer. Tron, the electronic warrior (above, from Walt Disney Productions), is a character from the new fantasy movie of the same name. Special effects in "Tron" combine computer graphics and live actors. Bell Laboratory designers (left) use terminal for creating an IC pattern.



Protein molecules of a virus were created in a colorful computer-graphics display at Lawrence Livermore National Laboratory (top, right). At Warner-Lambert, a drug firm, researchers use a graphics plot on paper to study a molecule (top, left). Data computerized from blueprints and other sources enable viewer to "walk" through Times Square (middle, left). The scene was computerized by Digital Effects, Inc. Complex computer-graphics programs for drafting and mechanical design add shading and other enhancements to realism on CRT display from Computervision (middle, right). New programs for displaying surfaces can simulate the skin of an orange or hues of different metals. The colorful abstraction on the right is actually a summation of mathematical functions in graphical form, plotted by M. Prueitt.



Super Guppies

fly impossible cargoes



A Super Guppy on the Tarmac in Madrid. The nose swings 120 degrees to load Airbus horizontal stabilizers for trip to Toulouse.

Huge, unwieldy aircraft parts, already assembled, are the regular riders on this special transport

By CHARLES A. MILLER

When Europe's Airbus Industrie builds its A300 and new A310, the parts fly by Super Guppy. Many subassemblies for the consortium's airplanes, which are fabricated in widespread assembly lines, are too big to fit on the narrow roads or under bridges on the waterways of Europe, so the components are airlifted to their destination.

The Super Guppy, one of the strangest-looking planes made, can carry these loads easily—no other plane can. To ship the same cargoes by land would require that some of the parts be left unassembled. Airbus, however, transports all major A300 and A310 parts completely assembled: Fuselage sections from Germany, wings from England, and tails from Spain all go aboard a Guppy for transport to the main assembly plant in Toulouse, France.

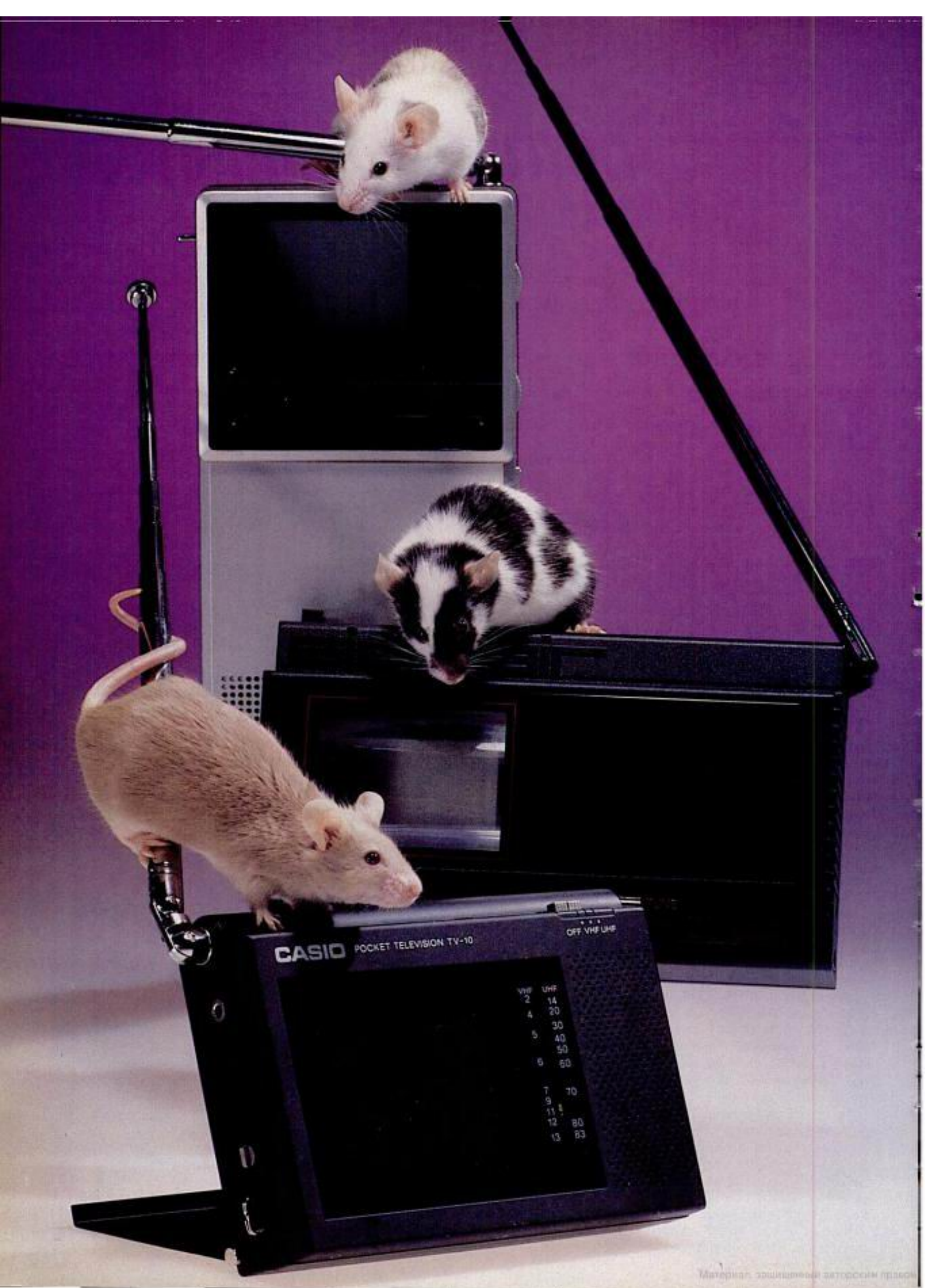
Guppies are operated for Airbus by UTA Industries. The

planes are modified Boeing Stratocruisers dating from the '40's that have been reworked, in part, by an American company, Aerospace Lines, in Santa Barbara, Calif. There are three of the breakfront airplanes now in operation, and another is due to join the fleet early next year.

The Guppies reduce the risk of damage to cargoes. Conventional shipping requires loading and unloading by third-party handlers, who may not be familiar with the problems of sometimes fragile aerospace cargoes. The Guppies fly directly from plant to plant, where loading and unloading is done by trained personnel.

The cost of transport, too, is lower when the components are sent by air, especially when considering production time: Under the present system no part is out of the production line for more than 48 hours at a time.

A Guppy has a payload of 54,000 lbs. and can carry objects almost 25 ft. across and 32 ft. long, with smaller-diameter loads going in the aft section of its 111-ft. cargo compartment. It is powered by four Allison turboprops and cruises at 285 mph. The lines for the engines and control surfaces are not disturbed when the nose is opened up, thanks to special rigging at the fuselage hinge. **E**



CASIO POCKET TELEVISION TV-10

OFF VHF UHF

VHF	UHF
2	14
4	20
5	30
6	40
7	50
8	60
9	70
10	80
11	83
12	
13	

Flat screens shrink new pocket TVs

● New mini-TVs travel anywhere with you—or let you catch action up close at the ballpark. Flat cathode-ray tubes, complex liquid-crystal displays, and advanced single-chip TV circuits make these carry-along sets possible. Models with full-color displays will soon be available.

By JOHN FREE

Photo by Greg Sharkey

At last, they're here. Flat-screen TV sets, always just around the corner, are now in stores. And more pocket-sized models are being introduced.

The sets, which provide viewable but detail-limited pictures, are being gobbled up by gadget-hungry shoppers. But whether they become a mass-market product, as have personal-stereo tape machines, remains to be seen.

I tried several of these remarkably compact sets and quickly noticed distinct differences in picture quality and channel-tuning sensitivity. Because the flat-screen market is so new and my sampling limited, however, direct comparisons of brands is premature. Before investing in one of these new sets, you should try it out if possible under conditions similar to those under which you'll be using the set.

Despite the variety of flat-screen technologies under development [PS, June '81], two of the black-and-white pocket sets use new versions of the familiar cathode-ray tube (CRT). The Sony Watchman FD-210, which appeared in 1982 ["Go-Anywhere TV," PS, Nov. '82], has a flattened, paddle-shape picture tube. Now the firm is marketing its second-generation Watchman, about 20 percent smaller and lighter—and less expensive—than the original.

Meanwhile, from a 19th-century water-bottling plant converted into re-

search labs in Cambridge, England, inventor Sir Clive Sinclair hatched the pocket-sized model he's been developing for the past five years.

The Sinclair Research Ltd. model designed for European use ["Little Flat-Screen TV," PS, Dec. '83] is being made and distributed by Timex in Britain. The set, shown in dummy form on the facing page, also has a flat-screen CRT, but it draws relatively little current; the set is based on a single microcircuit—a combination that makes for a continuous-use battery life of about 15 hours, according to Sinclair. The UHF model distributed in Europe automatically switches to various 625- or 525-line TV standards. A newer model, with an additional VHF tuner for the U.S. (to be marketed in 1984 by Sinclair Research Ltd., 50 Staniford St., Boston, Mass. 02114), will retain this capability.

Casio is the only firm at this writing offering a liquid-crystal-display (LCD) monochrome pocket set. Seiko has an LCD wristwatch-TV model with a calculator-size tuner-amplifier [PS, April '83]. The Casio TV-10, with a 2.75-inch screen, uses the twisted-nematic type of LCD, similar to that used in watches and calculators. The TV-10 can use bright ambient light reflected from its thousands of tiny LCD elements; a switch activates a

solid-state electroluminescent element behind the LCD panel to display pictures in dim light. LCDs have low power requirements and thus permit long battery life, but they often have poor picture contrast. This problem was evident in the TV-10 that I tried.

Although it's not yet in stores here, a color LCD pocket set from Seiko [PS cover story, Nov. '83] is expected to go on sale soon. According to PS Executive Editor Herb Shuldiner, who saw the prototype in Japan, the set displays a good color picture. In the second half of 1984, Sanyo is expected to market a color LCD TV with a three-inch screen (one inch larger than Seiko's). The Sanyo set is expected to sell for about \$420 there. In color LCD sets, three LC picture elements, each with a color filter in front of it, are necessary to form a color triad—a red, green, and blue combination to form a color-picture element. Compared with a monochrome LCD set with the same number of LC elements, picture detail on the screen is diminished, but the color creates a more satisfying picture.

How popular will flat-screen pocket TV become? Says Clive Sinclair of his latest brainchild: "I believe that it and its successors can achieve for television what the transistor radio did for wireless—and create a new one-person product." **PS**

PS buyer's guide to flat-screen pocket TVs

Maker	Model	Price (\$)	Screen size (in.)	Screen type	Size (H, W, D: in.)	Weight (oz.)	Battery type, life	TV standard*	Comments
Casio	TV-10	200	2.75	LCD	3 1/16, 4 11/16, 1	12	3 AAs, 7 hrs.	M	Has LCD backlight switch, brightness control
Sinclair Research	Pocket TV	About 100	2	CRT	3 1/2, 5 1/2, 1 1/4	10	Flat, 15 hrs.	B, G, H, I	Automatic TV-standard switching
Sony	FD-20A	200	2	CRT	6 5/8, 3 3/4, 1 5/8	18	4 AAs, 10 hrs.	M	Video-in (VCR) jack

*TV standard M is the 525-line-resolution format for North America and a number of other countries; B, G, H, and I are 625-line-resolution standards for Europe and Great Britain.

Flat-screen sets (from top: Sony FD-20A, Sinclair Pocket TV, Casio TV-10) are likely to multiply rapidly.

So long, jets? Ingenious new blades make *prop*

Bizarre-looking propellers with eight or more slender, twisting blades are being proved in wind tunnels and will soon be flight-tested. The goal: prop liners that fly at jet speeds—on 20 to 30 percent less fuel. Experts say the technology is too good to pass up.

By JIM SCHEFTER

The throaty whine of the scimitar-shaped propeller blades changes pitch slightly, just enough to let the 120 passengers know that they've reached their 37,000-foot cruising altitude. Outside, the propellers churn through the thin air at 900 rpm, and the airliner builds speed to nearly 550 mph.

To passengers long accustomed to jet travel, the trip seems routine. In most respects it is. But the propeller-driven plane they are flying—at jet-like speeds—is the first of a new generation of air transports.

After a quarter-century of jet domi-

nation, propellers may be on the way back. The new propellers, called propfans, are dramatically different from any that came before. Turbine-powered, with eight or more thin, helically curved blades, they can deliver the speed of jets while cutting fuel consumption by 20 to 30 percent.

"You're going to see propeller-driven airliners again by the 1990s," predicts William E. Arndt, manager of the prop-fan test-assessment program at the Lockheed-Georgia Co. "The technology is too good to pass up."

The new prop-fans are the result of a 10-year development effort by NASA and private industry. The program moved slowly until last year. "There was a long list of objections to propel-

lers," says Bruce Gordon of General Electric Co., "including noise, vibration, complexity, and maintenance costs."

Then in mid-1984, GE suddenly announced independent development of a radical new engine-propeller combination. Almost simultaneously, NASA signed a \$59.3 million contract with the Lockheed-Georgia Co. to flight-test a prop-fan developed under NASA sponsorship by Hamilton Standard. The agency also provided fresh funding for the GE project.

To discover what triggered this new surge of an old technology, I traveled to Lockheed's sprawling plant in Marietta, Ga., then to Hamilton Standard in Windsor Locks, Conn. And I



liners as fast as jets

talked to the manager of GE's propfan program.

Reinventing the prop

The prop-fan, like the turboprops developed in the late 1950s, is a hybrid that mates a turbine engine with a propeller. Power from the turbine turns the propeller, which moves air back and provides forward thrust. In a pure jet engine, the hot combustion gases from the turbine are exhausted backward to provide thrust.

"The most efficient way to power an aircraft is to generate thrust with a propeller," Arndt said. In fact, a turbofan jet engine, the sort used on today's jetliners, is a series of multi-bladed fan-like propellers under a cowl. But cowl adds both weight and drag to an aircraft.

The best turbofan jet engines today convert only about 65 percent of the fuel energy into thrust. A propeller

Continued



Prop-fans look wildly different from conventional straight-blade propellers. From left to right in the painting are Hamilton Standard's single-rotating prop-fan, its counterrotating model, and General Electric's counterrotating UDF (unducted fan) design. GE is building a revolutionary engine-prop package (see text); Hamilton Standard's prop-fans will be mated with engines and nacelles made by others. Prop-fans are particularly suited for 80-to-160-passenger planes and military airlift planes that fly short hops—300 to 500 miles. Here the Hamilton Standard single-rotating prop is shown as a wing-mounted tractor design on a twin-engine airliner and on a four-engine Air Force airlifter. The counterrotating prop is shown aft-mounted, as a tractor in the painting and on the model (above). The cover painting shows it as a pusher. A single GE UDF engine powers a remotely piloted vehicle, and four of them, wing-mounted, power a military assault-airliner. Whether prop-fan engines will be wing- or aft-mounted on airliners depends primarily on results of noise tests to come: If prop noise is propagated through the air, mounting the engines aft, behind the rear cabin bulkhead, might reduce cabin noise. If it is propagated through the plane's structure, aft-mounting might not help. And wing-mounting offers some aerodynamic benefits.

"Airline

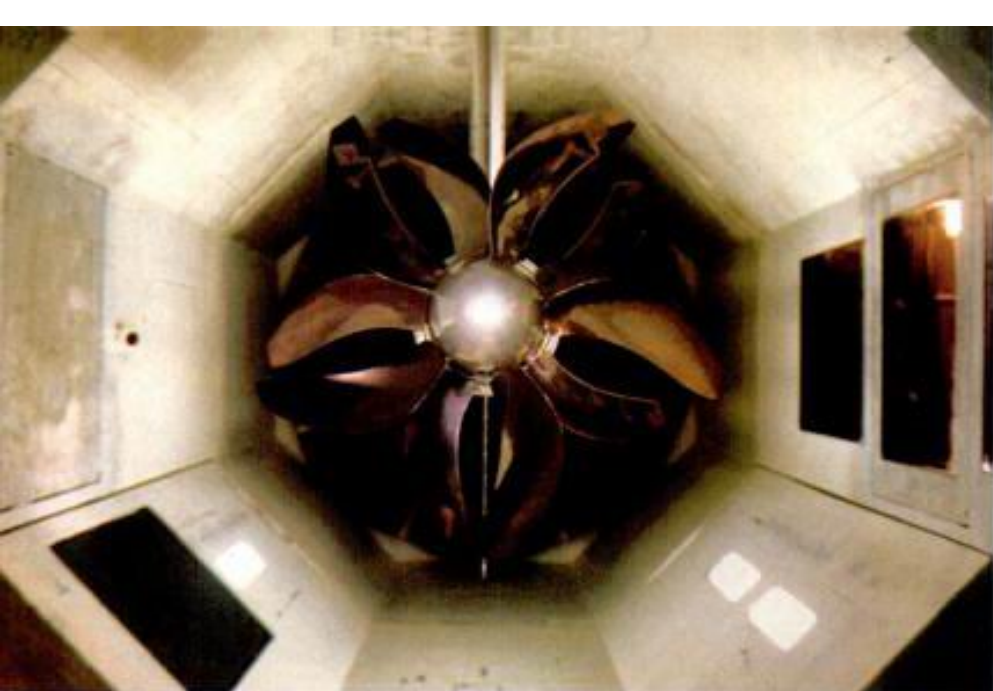
converts at least 80 percent. Those numbers give propellers a real edge in fuel economy.

Then why do jets dominate modern air transport? The answer is twofold. When the airlines introduced jets, fuel was cheap. The trade-off between high speed and fuel cost made jets economical. Today, fuel accounts for at least 30 percent of airline operating costs.

More important, traditional propellers with thick, straight blades run into a physical barrier at about Mach 0.6. (Mach 1 is the speed of sound at any given altitude. At typical jet altitudes, it is about 690 mph.) Above that speed, air passing through the propeller begins to compress. The added impact of compressed air on the blades causes shock waves, turbulence, and rapid pressure changes. These and the increased air density increase drag. In effect, the barrier has limited propeller aircraft to about 400 mph.

"To move beyond that you must maintain a smooth airflow above Mach 0.6," said Alfred L. Weisbrich of Hamilton Standard's Advanced Propulsion Systems. That's impossible with conventional propeller blades.

Enter the prop-fan, with blades that bend, lean, and twist from root to tip. Their fiberglass shells encase a foam core and an aluminum central spar. At Hamilton Standard's huge Connecticut plant, surrounded by acres of noisy machines, I ran my hand over a prop-fan blade nearing completion. Its airfoil shape not only tapered sharply toward the tip but varied in thickness over its entire length. I traced its trailing edge, where the blade slims to almost knifelike sharpness. Conven-



Wind-tunnel tests of Hamilton Standard's counterrotating prop-fan (top) indicate an efficiency of 89 percent at Mach 0.8. GE's UDF (unducted fan) engine-propeller design (center, left) has no gearbox; half of the turbine's fans will turn the leading propeller directly while the other half drive the rear prop (in the opposite direction) through a central shaft. Tests are to begin later this year. Hamilton Standard's single-rotation prop-fan (center, right) is to be flight-tested on a Gulfstream II business jet modified by Lockheed. The strange-looking result—with the prop-fan on the plane's left wing and nothing on its right wing—will fly in 1987 (left). In the air, test pilots will power down the jet's own aft-mounted left engine, allowing the prop-fan to take over. A 6,600-hp Allison turbine engine will provide power. A modified gearbox taken from a Lockheed P-3 will reduce the engine's 11,000 rpm to about 1,100.

The WHAT'S NEW magazine

MARCH 1985

\$1.75

Not just for ice,
snow, and mud—
**WHY YOUR NEXT
CAR WILL HAVE
4-WHEEL DRIVE**

Popular Science

So long, jets? Ingenious new superblades make
PROP LINERS AS FAST AS JETS



Low-cost electronic typewriters
that double as computer printers



New look in instant photography: *Polaroid's Spectra*

A new film format and chemistry, advanced electronics, ingenious lens system, and laser-printed enlargements transform the only player left in the instant-color game.

By ARTHUR FISHER

The hoo-ha quotient in Los Angeles was incredible. There was everything from a lavish champagne party at a mansion seen on *Dallas* to a Hollywood-style presentation with Polynesian models and a giant walk-in replica of Polaroid's new camera. It was certainly the most elaborate product introduction I've ever witnessed—all in aid of the Spectra, which Polaroid Chairman William J. McCune Jr. called "a milestone in photography, like the SX-70."

The Spectra is not really the kind of revolutionary breakthrough exemplified by the 1972 SX-70, the first instant camera to produce a dry, no-mess color print. But it is an attractive package of technical advances—some incremental, some radical—in film, optics, and electronics.

To the casual instant-camera user, the most important, instantly evident change is the film format. The image size is not only 10 percent larger than that of Polaroid 600 film, but rectangular. It measures $3\frac{3}{16}$ by $2\frac{7}{8}$ inches, the same proportion as a four by five. The change to a rectangular format was made as a result of an intensive market survey.

Dual chemistry

The film's chemistry, too, is changed. According to Peter O. Kliem, Polaroid's director of research, Spectra film is the only color medium in the world that uses two different chemical mechanisms in a single film structure: a new approach called "thiazolidine dye release" for the blue-sensitive layers, and the normal Polaroid dye developer chemistry for the red- and green-sensitive layers.

The net result of this unique dual-chemistry system, Kliem said, is to modulate chemical interactions among the various layers, resulting in improved color rendition and satura-

tion, especially of yellow, magenta, and green.

Unique optics

Bundled within the camera are other examples of advanced technology that the casual photographer will probably not pay much attention to, but that certainly contribute to the Spectra's finesse. Among these are:

- A unique 125-mm, f/10 three-element lens system called "Quintic," for the five levels of polynomials in the equation needed to define its aspherical shape. A kidney-shaped central element moves laterally, not back and forth, in response to the sonar autofocus system, thus saving space.

- A viewfinder, combining six lenses, four mirrors, and two prisms, that displays distance and "good-picture, bad-picture" information in color.

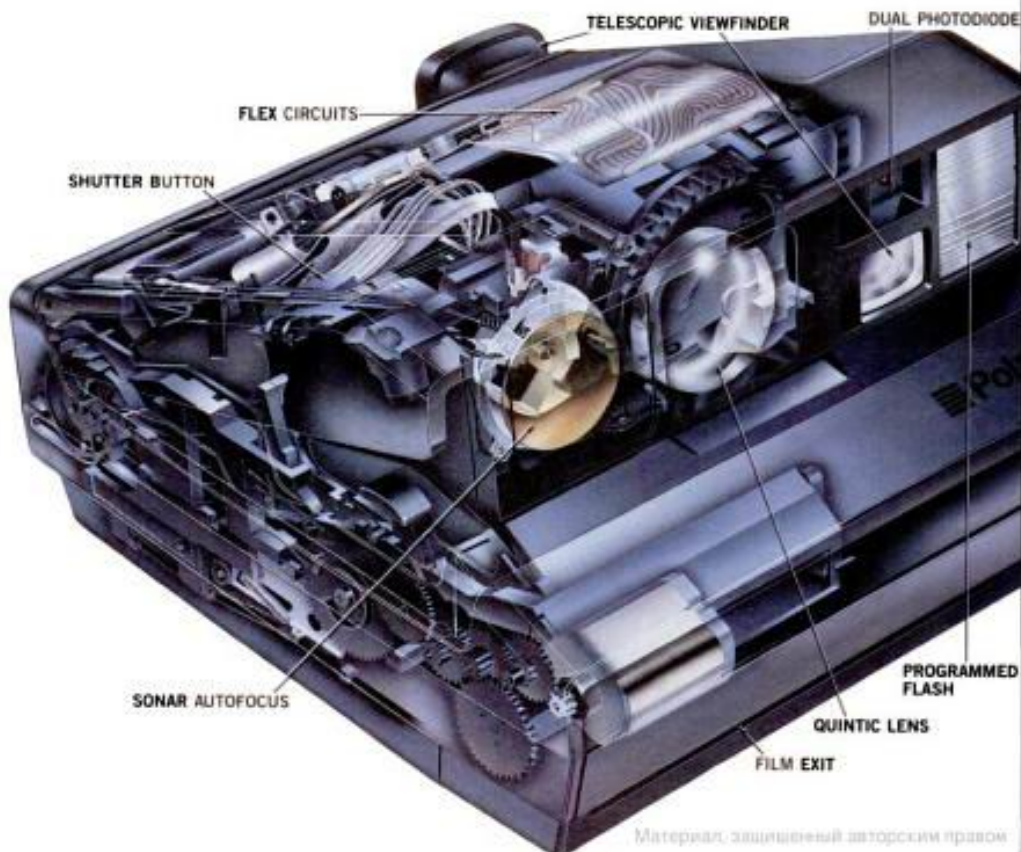
- A dual photodiode that measures both visible and infrared reflected light from the subject to attain automatic exposures and controlled fill-flash when desired.

- Thirteen custom integrated-circuit chips, mounted on double-sided, multilayer Mylar plastic film flex circuits for all electronic functions.

- Rear-mounted controls to override flash, autofocus, and audible signals, and to adjust exposure and set a self-timer.

And there is something completely new to make users happy: a Polaroid laser-printing facility for making enlargements from Spectra prints. The examples I saw, ranging up to 11 by 14 inches, were terrific.

The list price of the Spectra is \$225. A 10-shot film pack costs \$11.75. And an accessory kit of five special-effects filters made by Cokin is \$26. ■



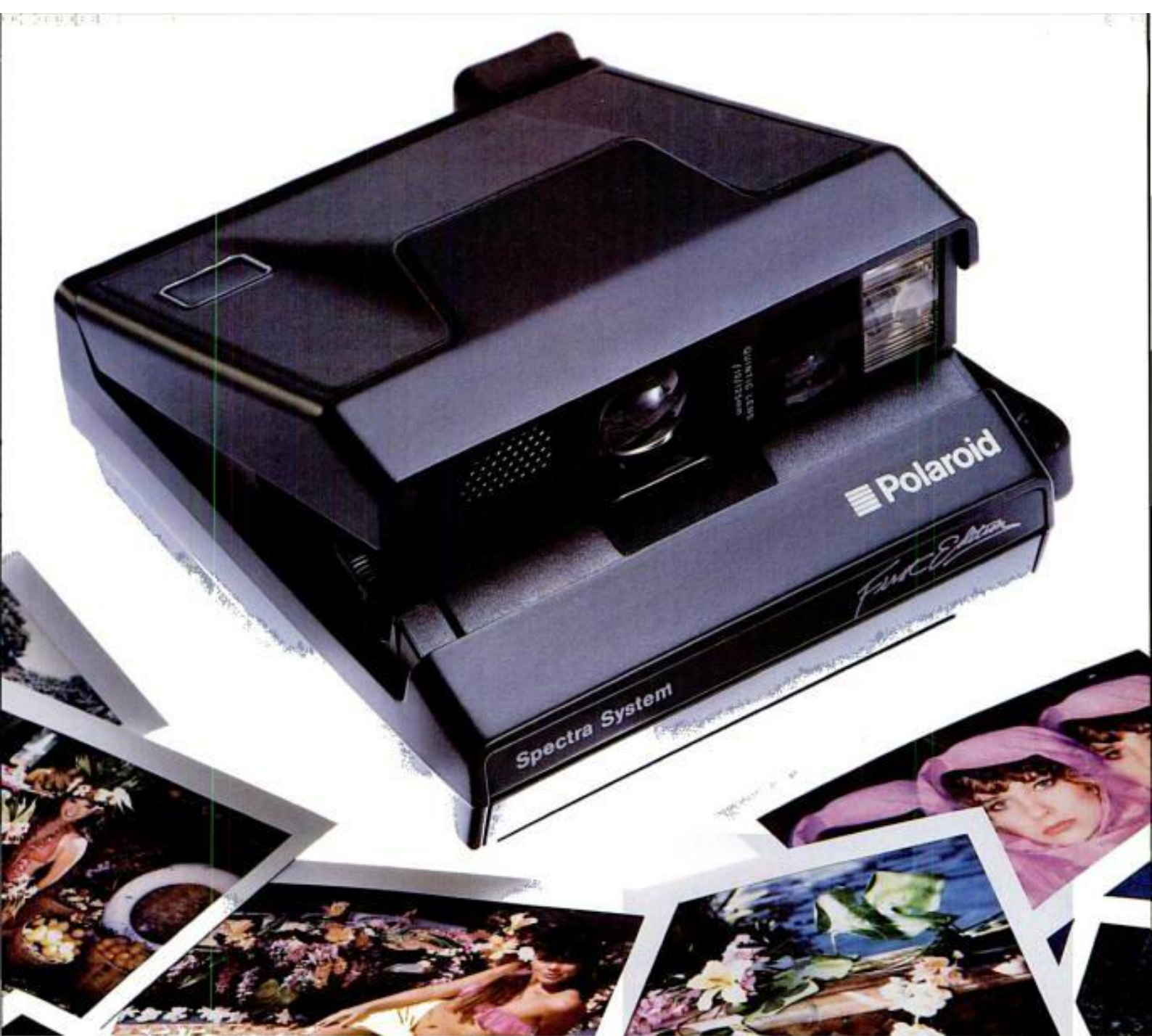
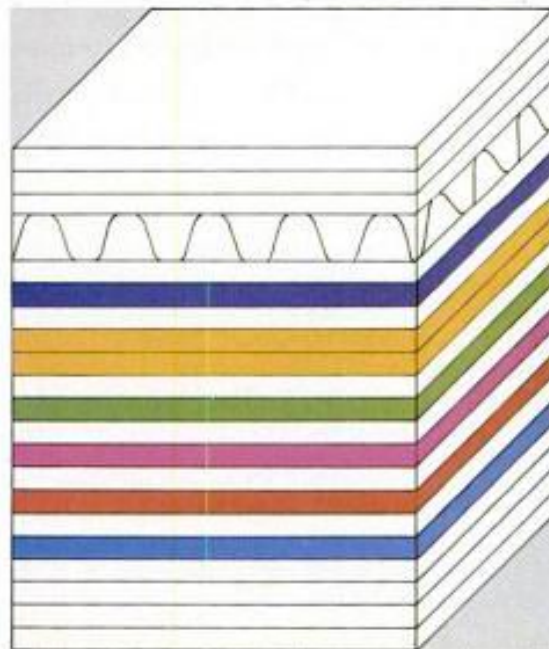


PHOTO BY GREG SHARKE

Spectra's dual-chemistry film



Transparent plastic support
Positive-image receiving layer
Clearing coat
Chemical processing reagent
Antiabrasion top coating
Blue-sensitive silver halide emulsion
Primary developer
Yellow-dye release layer
Yellow filter dye
Spacer layer containing silver ion scavenger
Green-sensitive silver halide emulsion
Spacer layer
Magenta dye developer and releasable antifoggant
Interlayer
Red-sensitive silver halide emulsion
Spacer layer
Cyan dye developer and releasable antifoggant
Timing layer
Spacer layer
Acid polymer layer
Opaque base

Folding wedge-shaped Spectra (above) has an elastomer surface and side strap for a comfortable binocular grip. The polycarbonate exterior contributes to its light weight (28 oz.). The phantom view (far left) reveals details of the camera's interior crammed with advanced optics and electronics. Spectra film (left) has 18 micro-thin layers divided into three color sandwiches to record blue, green, and yellow light. Dual chemistry uses dye developer and thiazolidine dye release imaging chemistries and newly developed molecules to provide enhanced brightness and color reproduction.

Arrowhead windmill

Vertical-axis windmills have long appealed to designers because they are omnidirectional and can drive generating equipment located on the ground. Now a British engineer has developed a variable-geometry version that's also inexpensive to build.



By DAVID SCOTT

READING, ENGLAND

Leaning across his paper-strewn desk at Reading University, where he heads the engineering department's energy group, Dr. Peter Musgrove was intent on explaining the features of his vertical-axis wind turbine. "It's got many advantages over the usual horizontal-axis turbine," he told me. "The first big point is that it's omnidirectional; no steering mechanism is needed to head the rotor into the wind, which cuts complexity and cost."

With a traditional horizontal layout,

Musgrove continued, the rotor nacelle must house either the entire gearbox and generator or bulky right-angle bevel gearing, which makes the tower top-heavy and expensive.

Further, vertical windmill blades have a constant airfoil section along their length, making them simple and cheap to produce. With these points in their favor, Musgrove feels that vertical-axis turbines are now a viable candidate for commercial electricity generation. His grandest scenario envisages offshore wind farms of perhaps 150 giant turbines with 300-foot-diameter rotors grouped together.

The vertical-axis concept is not new. It dates back 50 years to the original

Darrieus design, which had two or more curved blades of looping "troposkein" form, similar to the natural line taken by a jump rope in midair. Musgrove began working with the Darrieus rotor at Reading in 1974, but he soon became aware that it had several drawbacks.

"The blades are difficult to make," he told me, "and only the central portions produce useful energy. They have a fixed pitch, so they can't be feathered to control power output. And the greater height of the rotor compared with a conventional turbine requires a taller tower, usually with guy wires that take up a large amount of ground area."



From this starting point, Musgrove progressed to an H-shaped rotor configuration, which provides speed control by pivoting the upper tips of its two blades outward as it reaches design speed. The resulting V-shape has less swept area, so the rotor slows down. I saw a prototype running at the nearby Rutherford Appleton Laboratory, which works closely with Reading on the windmill project. It has a 20-foot-diameter rotor that drives a five-kilowatt generator located in a small shed. Extensive tests with this rig led to a major design improvement: arrowhead blades.

These two-piece blades are centrally hinged to the crossarm. As before, they

normally run straight and upright for maximum energy absorption. But with increasing wind speeds, the rotors fold inward, decreasing frontal area without causing unwanted vertical forces—a nasty tendency of the H-pattern rotors. The arrowhead-blade angles are adjusted by hydraulically activated push rods that are controlled by a wind-speed sensor linked to a computer. A machine of this type, about the size of the Rutherford unit, has been operating since 1982 at Bembridge, on the Isle of Wight.

Now a much larger 150-kilowatt arrowhead turbine is under construction at Camarthen Bay, in Wales, with initial operation scheduled for next spring. It has an 82-foot-diameter rotor with steel arrowhead blades turning at up to 28 rpm. Blade angling to maintain constant speed is controlled by monitoring the generator's voltage output. Says Musgrove, "That's simpler and more effective than measuring wind velocity with an anemometer, which merely samples one point in space. Average speed across the swept area is what counts,



Planted on the sea bottom in shallow offshore waters (opposite page), vertical-axis turbines in this wind-farm concept stand on 250-ft. towers. Each 75-ton rotor powers a 3-MW generator. Locating windmills at sea reduces their noise impact. An arrowhead windmill being built in Wales (left) contains only first-stage step-up gearing at the top of the tower. This design minimizes the weight the tower must support. The drive shaft powers a second-stage gearbox and generating equipment located in the base of the 80-ft. tower, where it is easily accessible for maintenance. An experimental windmill (above) is located on the Isle of Wight. Hinged blades pivot on longer support struts; shorter struts are moved in and out by sliding links in the crossarm. Varying the swept area controls rotor speed.

so we're using the windmill itself as a sensor."

The 150-kilowatt machine, to be on trial for two years, is a one-quarter scale prototype of future windmills Musgrove sees making an important contribution to Britain's electricity needs. The British government apparently thinks similarly: Funding for alternate-energy research is now heavily biased toward wind-power projects at the expense of ocean-wave and solar-power efforts.

Another small prototype commercial windmill, intended for islands and other remote communities, is in the late stages of fabrication. Its 56-foot arrowhead rotor will produce 100 kilowatts of electricity. Testing of the windmill will be conducted on the Scilly Isles, off the southeastern coast of England.

It looks as if this latest generation of wind turbines may be about to break out of university-research-project status and into the marketplace: Several British construction firms have already formed a business consortium to get in on the vertical-axis act. ■

ON BASE IN SPACE

A bold step into a new era of manned exploration, the U.S. space station will be the largest structure ever put into orbit. The engineering challenges are formidable.

By **JIM SCHEFTER**

Illustrations by Vincent Di Fate

It's just past twilight in the southern United States when a massive glowing ball, larger than Venus and brighter than the full moon, rises suddenly from the northwestern horizon. Moments later, like puppies trailing their master, smaller points of light, first one, then another, appear in the same celestial track.

Climbing swiftly toward the zenith, the spectacular objects race southeast, dominating the night sky until they fall from view less than seven minutes later. Aboard the larger object, comfortably housed in a pod of spacious modules and nodes suspended below the midpoint of a massive 160-meter girder, eight scientists and astronauts pause a moment to glance at city lights twinkling far below.

If anyone happens to be in one of two cupolas, where windows give a 360-degree view, the eight giant solar panels—four sprouting from each end section of the long



girder—will be sparkling with reflected sunlight. The view from space never loses its thrill, but a moment is all the crew has to spare. There's work to be done to keep the U.S. space station and its racks of experiments and instruments operating.

Inside the smaller objects following about 100 miles behind, no one is aboard to enjoy the view. The pair are the private U.S. Industrial Space Facility and the European Man-Tended Free Flyer, both unmanned labs going about their automated business of producing strange new materials, growing crystals of unearthly size and purity, or simply exposing experimental devices to the microgravity of space.

In fact, there may be only one unmanned factory, not two. In a move to tie space-station funding to the privately built ISF, Congress has delayed and may have inadver-



tently killed the American lab. Its demise would give the European Space Agency a monopoly over automated space manufacturing.

But the space station itself is emerging from its cocoon of planning, and its shape can be seen clearly at last. I talked with experts at NASA in Washington, D.C., at the Marshall Space Flight Center in Huntsville, Ala., where the heart of the station—its living quarters and laboratory—are to be built, and at the Southern California aerospace company where the station's main truss is being designed. Here's what I discovered.

A little more than seven years from now, sometime in the fall of 1996, the drama of Americans living and working full-time in space will become reality. Not everyone is happy. Some scientists and politicians are not convinced that a space station is needed, while others complain that

Orbiting 235 miles above Earth and powered by huge solar panels, the space station will allow U.S. and foreign astronauts to live and work in space on a permanent basis. The first phase will be completed by 1997. Then the station will continue to evolve as new scientific uses arise.

its cost will take funding away from planetary and other missions. Even so, after more than half a decade of designing, revising, scheduling, and rescheduling its plans to put a large permanent station in orbit around Earth, the United States is finally moving ahead firmly with a whittled-down, but still impressive, space laboratory.

What \$15 billion will buy

In current dollars, U.S. funding will be about \$15 billion. That will buy the station's main structure, solar ar-

Continued

rays, and support hardware. It will also buy four large nodes, each with a large interior volume and six ports for connecting living quarters, laboratories, and other modules. Two nodes will sprout viewing cupolas outfitted with controls and data screens to allow astronauts unobstructed vision as they operate external systems or guide a shuttle into its berth.

Finally, the price tag includes a mixed set of modules to be attached to the nodes—air-lock modules for astronauts entering or leaving the station, twin docking tunnels for the shuttle, a medium-sized logistics module containing much of the station's operating systems, and two large units—a habitation module and a laboratory module—for living and working.

Three more large modules, a laboratory provided by Europe and laboratory and logistics modules from Japan, will be added during the first phase of construction. And a pair of remote manipulator arms, similar to the arm now carried by the American space shuttle and critical to piecing together the station and guiding the shuttle to its berth, will be provided by Canada. Total cost of the operational station, including both U.S. and international contributions, is expected to exceed \$20 billion.

The station was originally planned for full-time occupation by scientists and astronauts in 1992. If NASA sticks to its current schedule—a timetable that will be affected more by future budgets than by technical obstacles—the first space-station elements now will be packed into a shuttle payload bay and vaulted into orbit in early 1995. A total of 20 shuttle flights running through 1997 will bring the first phase of space-station construction to an end. The station will then be ready for eight full-time residents.

Private space facilities

The one or two unmanned space factories now planned complete the space-station system. If current plans aren't derailed in Congress, the privately owned U.S. Industrial Space Facility—or something similar called the Commercially Developed Space Facility (CDSF)—will be carried

into orbit in 1993 or '94. But as this article goes to press, its fate is a major question mark.

The Europeans are more certain. They expect to launch their own man-tended free-flyer facility to join the space-station armada in late 1996 or early 1997.

Former astronaut Joseph Allen calls the ISF a "toolshed." Pioneer space designer Maxime Faget calls it "a pathfinder for the space station." NASA isn't sure, but is caught in the middle of an argument over its worth.

"It would carry experimental racks identical to the station," said Faget, now chief executive officer of Space Industries in Houston, which designed and may orbit the little lab. Faget knows how to make things work in space. He's a pioneer whose designs for NASA strongly influenced every manned space program from Mercury to the shuttle.

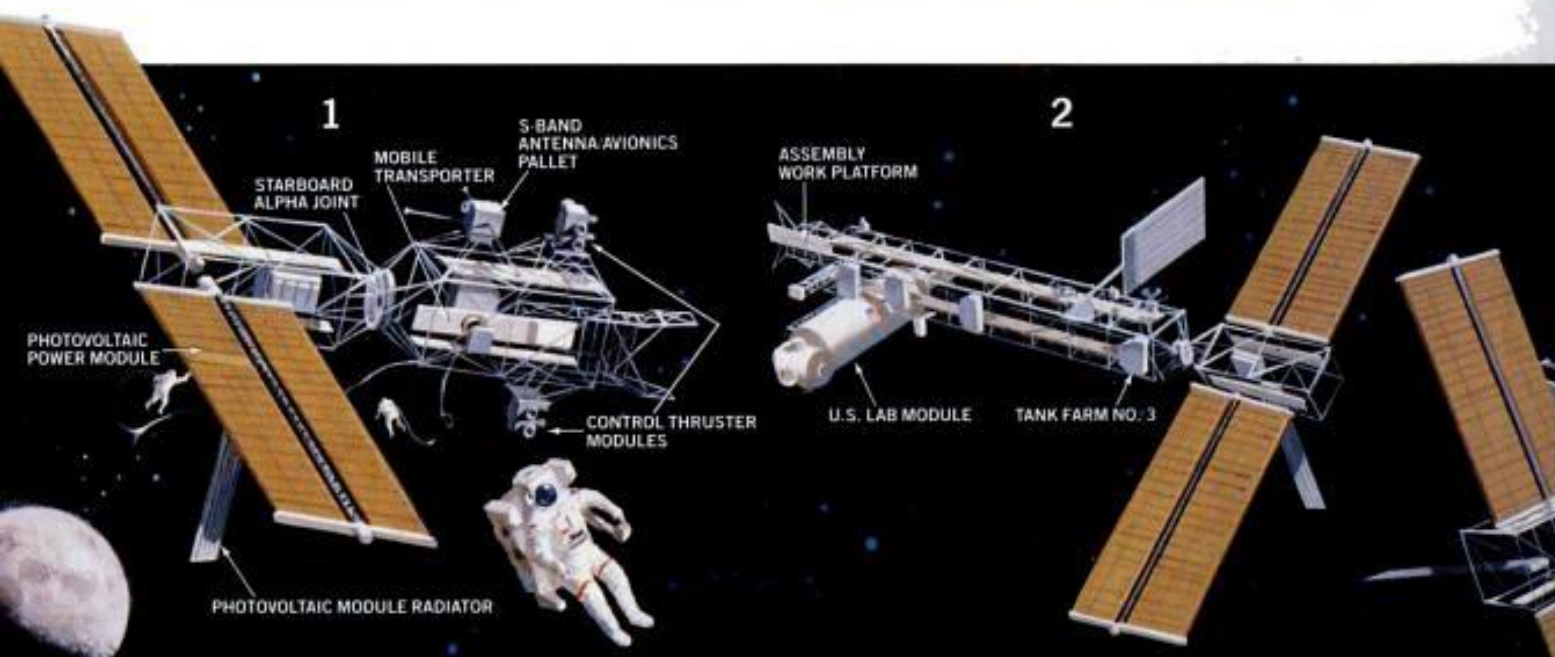
Faget began pushing the ISF concept after retiring from NASA in 1981. He was later joined by Allen, now president of Space Industries, and others who saw a niche in space for private industry.

On paper (most of the design and engineering is completed and the craft is ready to be built) the ISF is a \$1-billion pressurized tube with solar-panel wings, sort of an unmanned mini-laboratory. With a 14½-foot diameter and 2,500 cubic feet of internal volume, it could be carried into orbit by a single space shuttle, already filled with self-contained space experiments and autonomous systems for materials processing.

After leaving the shuttle bay, a pair of 100-foot solar arrays, providing up to 10.8 kilowatts of power, would deploy and the ISF's automated equipment would begin to work. The lab's interior would be pressurized but unmanned. Once every four to six months, it would be docked to a visiting shuttle. Astronaut crews would spend a day or two retrieving and replacing equipment, then leave the ISF to its lonely autonomy.

In concept, the facility has the same relationship to the space station that a pickup truck has to an 18-wheeler. But its future is now tied to the bigger program.

Faget foresaw that a privately owned laboratory would



Assembly plan calls for astronauts to leave a stable, fully powered section of the space station in orbit after the first mission (1). Truss elements go together to make three bays to which electronics packages, fuel-storage tanks, solar panels, and a mobile transporter—which moves along the truss like a trolley car and will eventually carry a robot arm—are attached. A pivot joint allows the solar panels to turn for maximum exposure to the sun. A large thermal radia-

tor bleeds heat from the solar module.

After only four assembly missions, the U.S. space station has grown to about half of its final size (2). The pressurized laboratory module allows "man-tended capability" with astronauts working inside part-time. The device protruding from the lab module is a shuttle docking adapter and tunnel. Control gyros maintain the station's attitude in space.

The station can be permanently occupied by four or more

be used by fee-paying companies or university science departments for micro-gravity experiments and perhaps even small-scale production of pharmaceuticals or other materials. But private customers have been slow to sign up. In early 1988 President Reagan told NASA to take out a \$700-million lease on much of the ISF and to begin using it in space in 1993, several years before the space station would be ready. NASA balked, then agreed on the condition that bids for building the little lab—now to be called the Commercially Developed Space Facility—be open to all. At that point only Faget's Space Industries team, which included Boeing and General Electric, seemed likely to bid.

Before NASA could follow through, Congress tied up the Industrial Space Facility by ordering its lease costs subtracted from space-station funds. Months of anguished and futile negotiation followed. In the end no real decision was made. With Congressional blessing, NASA ordered two more studies on the ISF and its usefulness. These reports will not be delivered until the middle of this year at the earliest.

If the Industrial Space Facility or Commercially Developed Space Facility is ever built, it will ultimately be moved into a trailing orbit behind the space station—close enough to be visited by shuttle crews, but far enough away to avoid contamination.

"Racks could be substituted back and forth between the space station and the ISF, so there's a strong incentive to use both," Faget said. "But the two are not the same."

Technology hurdles

With the ISF argument pushed to one side, NASA and aerospace-industry engineers face a few key technology hurdles before they can build the big station. One of them is critical. "We'll have a crew of eight with shuttle resupply missions every ninety days or so," said William R. Humphries, chief of the Life Support Branch at the Marshall Space Flight Center. "But the shuttle has a limited payload, so we're closing all the loops on the station." That means recycling water and oxygen, using new technologies never tried in space. "All the carbon dioxide will be

captured and cleaned, with oxygen returned to the cabin and carbon thrown away. Water will be cleaned and recycled in separate systems for potable and hygiene water."

The latter would be used in the station's clothes- and dishwashers, for showers, shaving, and other non-consumption activities. Even urine will be collected, cleansed, and put into the hygiene water system.

Water use totals 50 to 55 pounds per day for each crew member, Humphries said. "To replace it all would require five or six shuttle flights a year, just for water alone."

Reclaiming water

Instead, NASA and numbers of contractors are developing systems to reclaim, purify, and reuse every drop of water and every molecule of oxygen. Competing technologies will be evaluated and the best selected for full-scale development beginning next year, Humphries said. Even the methane gas generated by solid wastes might be useful as a fuel for the small rockets that help keep the station in orbit.

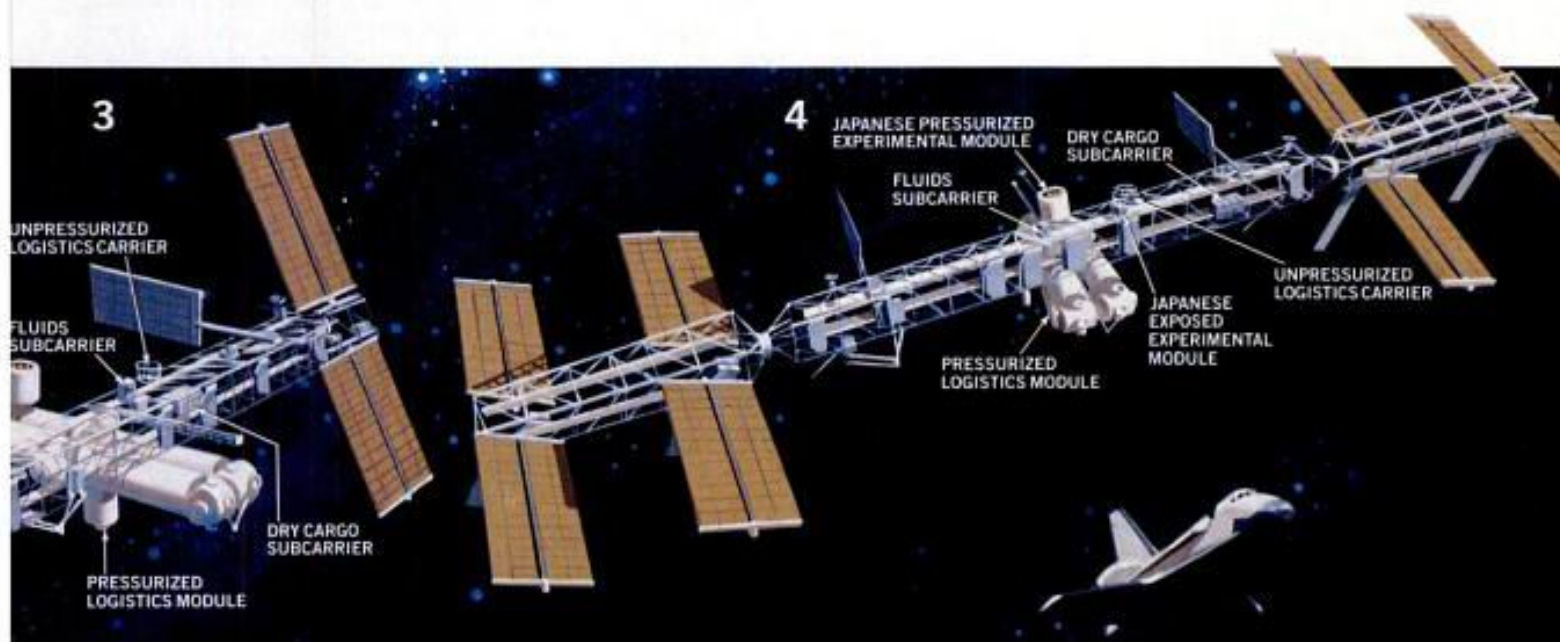
Initial results all look good, Humphries told me. "If this works out, there will be no water or oxygen resupply needed for the crew, and only occasionally for some experiments."

Other parts of the space station use existing technologies. Still, it will take 20 complex shuttle missions to get everything into space and assembled. When it's complete, the station will have a pod of pressurized modules slung under a long truss with solar panels at each end and a variety of other equipment attached above, below, and inside the truss.

"The first two flights will be the most difficult," said Daniel H. Herman, the program's chief engineer at NASA headquarters. "The truss has to be put together and the large solar arrays deployed. Once that's done, you have a completely functioning space structure, and you can relax."

In NASA's latest plan, astronauts on those flights will put together half of an orbiting erector set by assembling the first 60 meters of a massive truss. They'll also attach the first solar panels, electronics modules, attitude-control

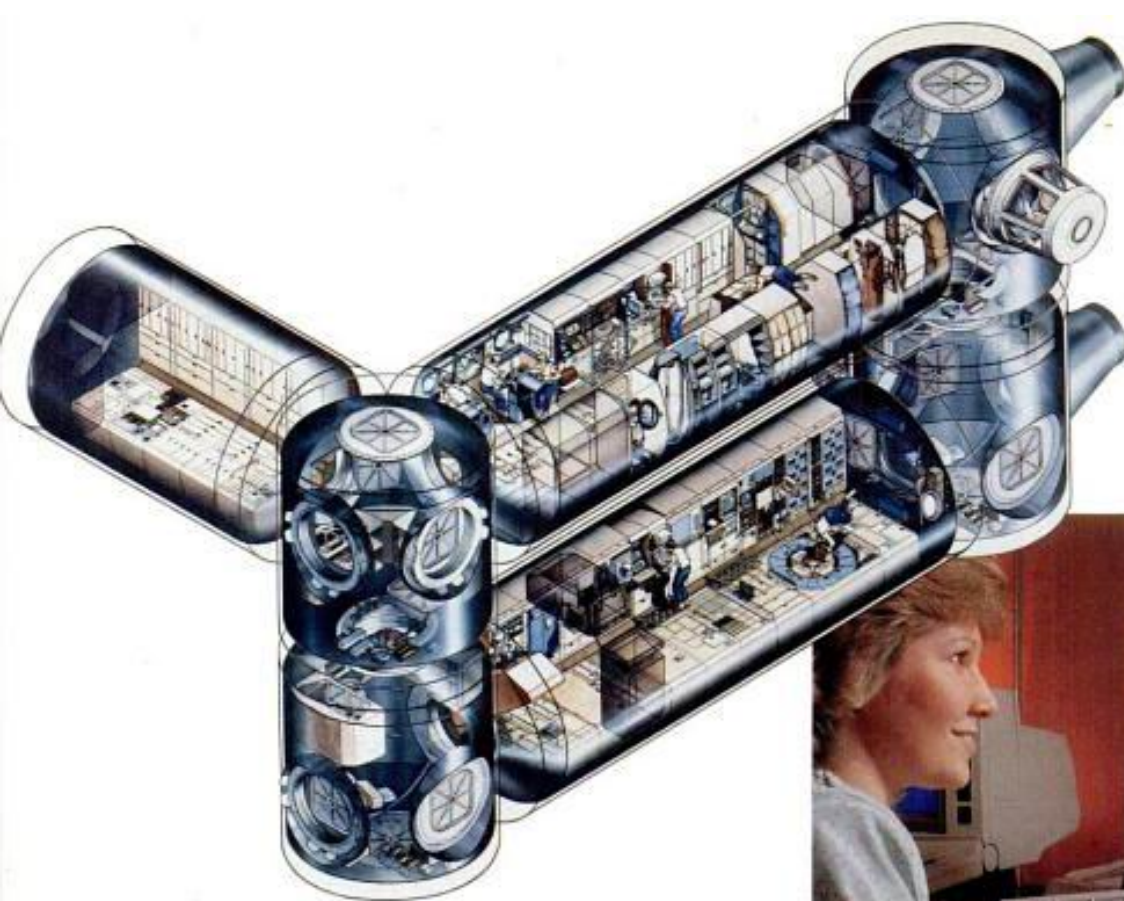
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people after the thirteenth assembly mission, which adds a large pressurized supply room (the logistics module) and several external supply carriers and pallets (3). In addition to extending the truss to its full 120-meter length, astronauts have installed additional solar panels, radiators, tank farms, and most major electronics and communications packages on flights 5 through 12. The U.S. habitation module is delivered and connected on the ninth mission, fol-

lowed by additional pressurized nodes and a cupola on missions 10 and 11. On some missions, most of the work is indoors as astronauts outfit modules with racks of scientific gear and equipment for day-to-day life in space.

After 20 shuttle flights, finally ready for its eight full-time residents, the U.S. space station has Japanese laboratories connected to the main living and working quarters, along with additional supply-room module (4).



Key modules for the space station (left) include habitation, with astronauts shown in rest and work areas (top center); laboratory (below habitation module); logistics, used for storage and transport of equipment and supplies (far left); and nodes for interconnections. A viewing cupola appears at far right in this Boeing concept.

Computer-aided design (see below) is used at the Marshall Space Flight Center for module planning.

thrusters, antennas, and other systems. The truss's open network of tubes will have a five-meter cross section and be loaded with equipment.

Putting it together will challenge the stamina and dexterity of astronauts assigned to the task. But both NASA engineers and experts at McDonnell Douglas Space Systems Co. in Huntington Beach, Calif., say that the job is within current technology. In late 1987 the company won the contract to design and build the truss and its support hardware.

"The truss will be carried up in the shuttle as a rack of poles," said George V. Butler, executive director of McDonnell Douglas's space station division. "Each pole will be labeled in sequence, and the astronauts will just put them together."

That scheme, company engineers decided, produces a truss that is stronger and more versatile than an erectable unit that would be launched in a folded configuration, then be extended or deployed in orbit. With the McDonnell Douglas system, only four separate components are needed—a five-meter pole for vertical and horizontal members, a 7.07-meter pole for diagonals, a small screw-in joist, and a ball joint that connects everything together.

Construction hardware

I looked at a full-scale mock-up of a truss section in Huntington Beach and marveled at its simplicity. "This is just one of three or four possibilities," Butler cautioned. "These are aluminum poles with an aluminum ball joint. But we're also looking at carbon-fiber poles and several other joint designs."

The final decision, he told me, will be made this year. The mock-up design looked good to me. The melon-sized ball joints were solid aluminum, each with 24 threaded holes drilled in precise "orbits" around its circumference. To build a truss, an astronaut would first screw an aluminum joist—a thick rod about five inches long with one end flanged and the other end a bolt—into one of the holes. A notched structural pole then would fit into the joist flange. Finally, the astronaut would pull down a locking sleeve prefitted over the end of the pole and with a quick twist



secure it tightly to the joist. After that, construction is simply a matter of extending the structure by adding more joints and joists, then attaching primary or diagonal poles.

At the busiest corners, eight poles—four primary and four diagonal—would be attached to a single joint. That leaves 16 more threaded holes for attaching other equipment including support structures that eventually will carry the pressurized modules, solar arrays, external space-station systems, and scientific hardware. Every hole won't be used, so the design is capable of growth and modification during the station's planned 30-year lifetime.

"It's a Tinkertoy setup," Butler told me. "It's a good engineering challenge, but not a big technical challenge."

On the first assembly mission in 1995, astronauts will plug together about 10 meters of truss, then install a pivot assembly about five meters wide. Beyond that point, they'll build another 15 meters of truss and install and deploy a pair of solar arrays. When unfurled, each array will stretch about 29 meters out from the truss. They'll produce peak power of about 18.75 kilowatts. The pivot, Butler explained, will allow the panels to track the sun while everything inboard of the pivot remains stable.

The first construction mission still won't be done. With the truss built, astronauts will return to the shuttle's payload bay and retrieve additional items. They'll install a telerobotic servicer platform that will eventually carry the robotic arm and move back and forth along the truss like a trolley car on rails. They'll also install the first of four tank farms for attitude-control fuel and other liquids, several avionics packages, a thermal radiator, and utility lines.

In space-station terms, utilities include fuel lines from

FUTURE WEAPON

Building Cheaper UAVs

CRUISE missiles and unmanned aerial vehicles (UAVs) cost a fraction of what piloted aircraft cost, and the Pentagon wants them to be even cheaper. Titan, of San Diego, has a plan to build \$1 million cruise missiles for \$60,000. The trick: Use off-the-shelf parts. Gulfstream, of Savannah, Ga., says it can build submarine-hunting UAVs by stripping the seats from its luxurious business jet and packing it with sensors.



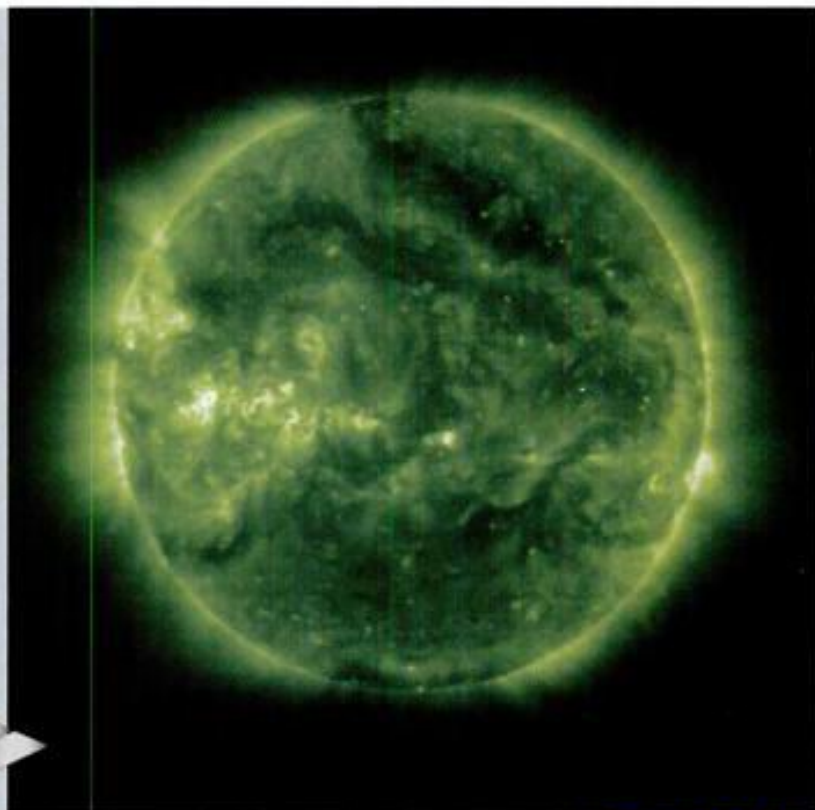
PM TECHWATCH

SPACE SHOTS

Solar Blast

TEN billion tons of flaming gas erupted from the sun in a coronal mass ejection that showered the Earth with a 2 million-mph blast of atomic particles. Matter from the high-energy event reached Earth on Nov. 5, 2003. It was recently found to be twice as powerful as suspected. The ejection was triggered by a solar flare that, fortunately, occurred on the side of the sun then facing away from Earth. This spared power grids and telecommunications systems. Sensors aboard NASA's SOHO sun-monitoring satellite, which took this image, were saturated but they survived.

- **Observatory:** SOHO
- **Location:** 1 million miles from Earth
- **Cost:** \$1 billion



NASA SOHO (SUN), JOHN BATCHELOR AND STUDIO LIDDELL (UAV)

(Please turn to page 31)



P-3C Orion antisubmarine aircraft uses radar, sonar, infrared and magnetic anomaly detector (in tail extension) to locate enemy. On-board Univac computer processes sensor data.



Military satellite relays ASW data that's been collected by ships, aircraft, submarines and listening networks.



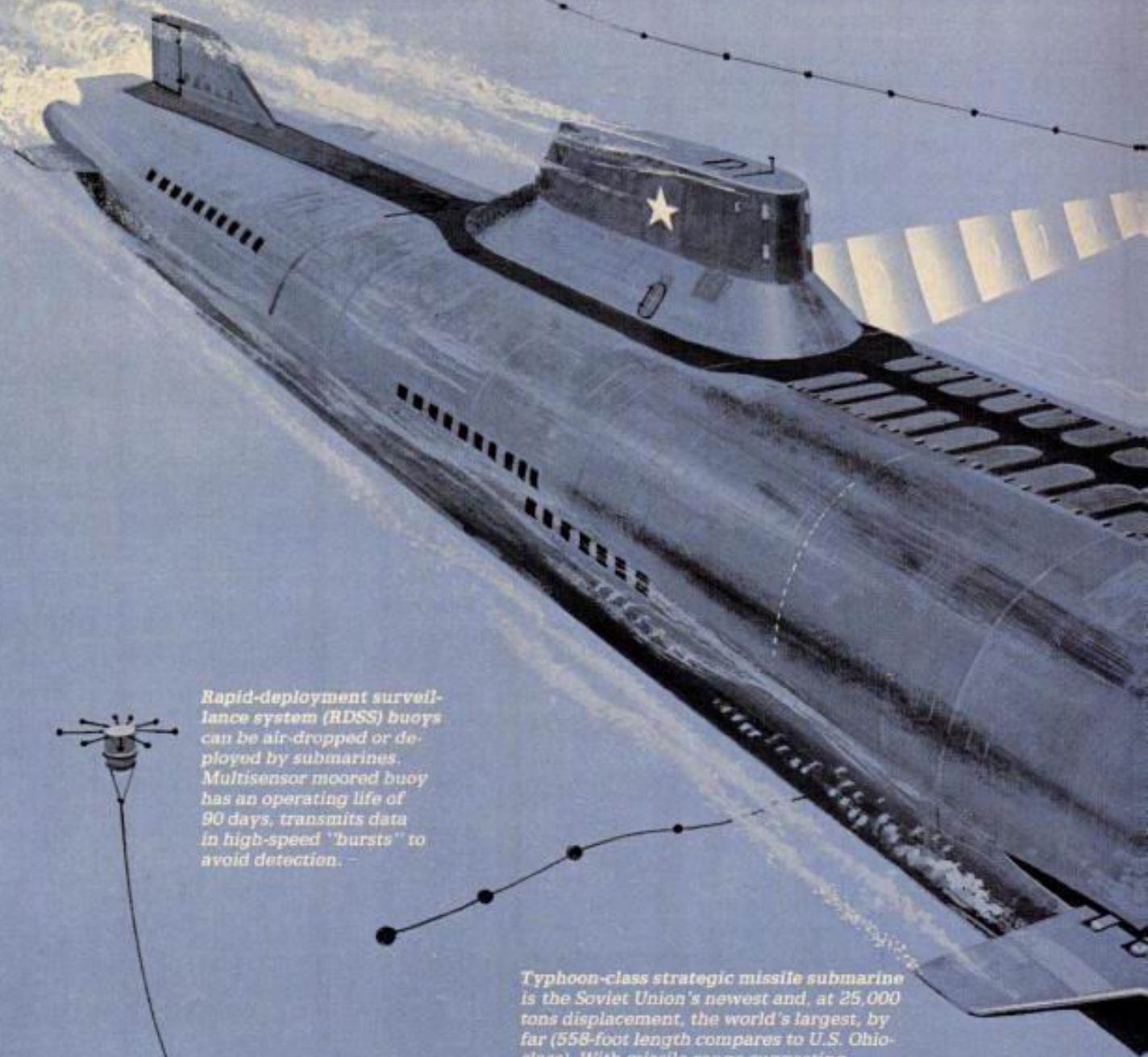
Lamps Mk. 111 helicopter tows sonobuoy for passive listening; also carries Mk. 46 ASW torpedoes and magnetic anomaly detection gear.



Surveillance Towed Array System, consisting of sensitive hydrophone string, will go to sea behind civilian-manned Navy ships this year.



Perry-class frigate is equipped with anti-sub missiles and torpedoes, can launch ASW helicopter.



Rapid-deployment surveillance system (RDSS) buoys can be air-dropped or deployed by submarines. Multisensor moored buoy has an operating life of 90 days, transmits data in high-speed "bursts" to avoid detection.

Typhoon-class strategic missile submarine is the Soviet Union's newest and, at 25,000 tons displacement, the world's largest, by far (558-foot length compares to U.S. Ohio-class). With missile range suggesting possible deployment in Pacific, Typhoon poses new threat to our ASW forces.

Military

A deadly game of hide-and-seek

Recent developments, both in the news and behind the scenes, have focused attention on antisubmarine warfare as one of the key military and political arenas for international relations in the near future. On the one hand, Soviet submarines seem to be penetrating the territorial waters of Baltic neighbor Sweden, a neutral country, at will, and escaping undetected. On the other, U.S. advances and planned deployment this year of new antisubmarine warfare (ASW) systems are seen as such a threat to the integrity of Soviet undersea operations that the Russians have brought them up at Strategic Arms Limitation talks.

A Soviet submarine (a nonnuclear, obsolescent Whiskey-class vessel) ran aground in Swedish waters in October 1981 and had to be towed off by the Swedes. A year later, the Swedish coastal defense forces believed one, or possibly two, submarines to be trapped in a small estuary.

Thus began a deadly game. The Whiskey sub, scanned during the 1981 refloating, was determined to have been carrying nuclear-tipped torpedoes. The Swedish forces began by dropping depth charges into the bay after sealing the exit with nets and patrol vessels. Because of Soviet activities, the Swedes had developed a whole range of weapons designed to disable modern U-boats without necessarily endangering the lives of their crews. Shaped-charge depth bombs punch small holes in the pressure hull, forcing the sub to surface without destroying it; torpedoes with small explosive charges home in on a fleeing sub's propellers, also forcing it to surface.

Last October, there was no final determination; either the Soviet sub escaped, was destroyed (unlikely) or, as the U.S.S.R. maintained, was not there to begin with. With its rugged, rocky bottom and constant intermingling of waters of differing temperatures and salinities, the Baltic

Illiac 4, a Burroughs computer, is used to process mass of listening and tracking data, separates submarine sounds from background in the ocean. New-generation supercomputers will soon take over.

Los Angeles-class hunter/killer nuclear submarine shadows enemy cruise-missile or strategic missile subs. Hydrophones and sonar detectors are situated forward; midships torpedo tubes fire conventional and wire-guided torpedoes, plus Subroc cruise missile. (Stand-off Subroc under development will range to 100 miles.)

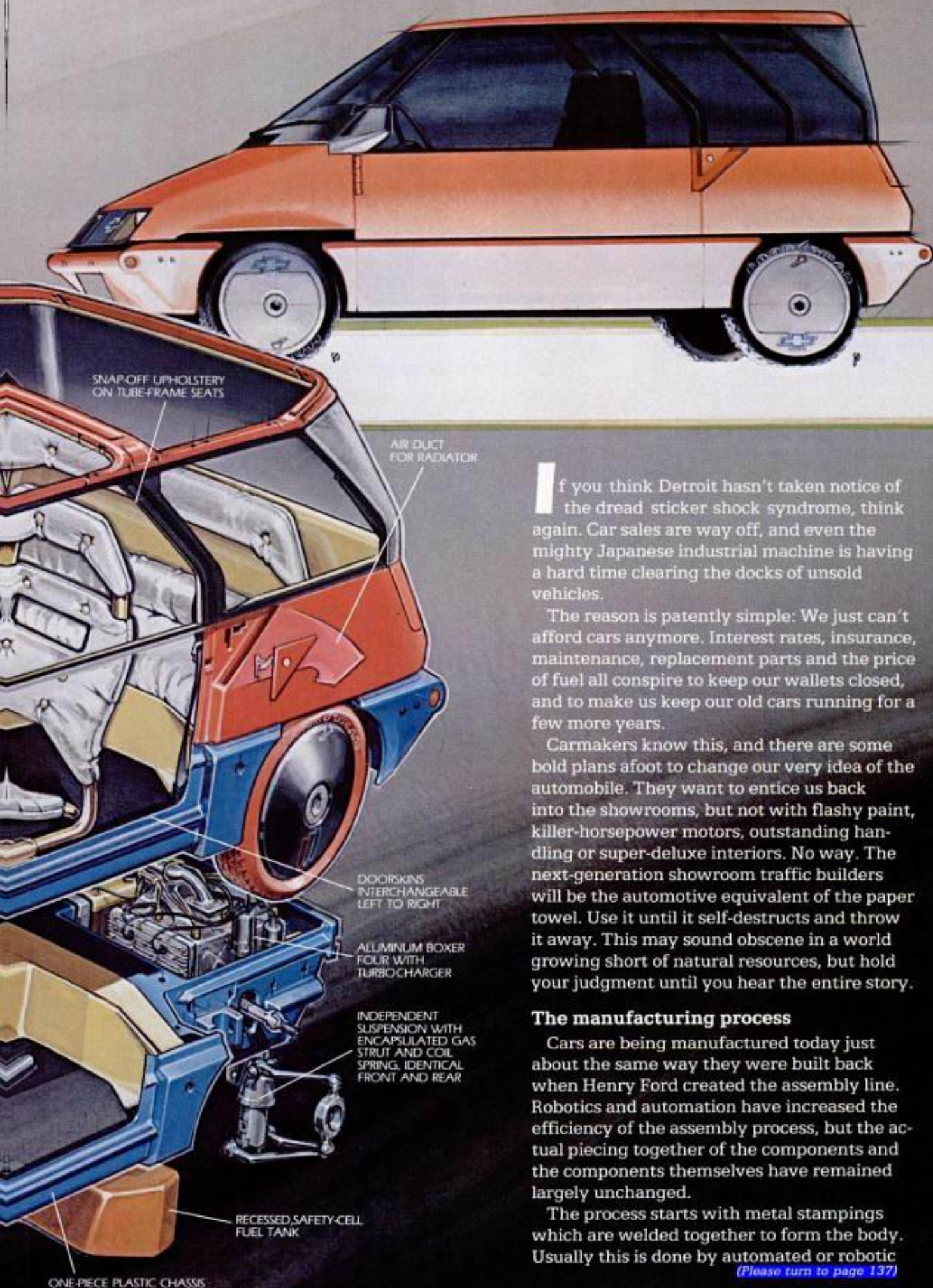
Hydrophone networks are deployed from shore stations, include up to thousands of individual phones. Bronco and Barrier are code names for sea-bottom chains placed in areas where Soviet submarines are known to pass, and off U.S. coasts.

COMING SOON: THE \$4,000 THROWAWAY CAR

It won't be fancy, fast or durable, but you can throw it away like an old pair of shoes.

BY LEN FRANK





If you think Detroit hasn't taken notice of the dread sticker shock syndrome, think again. Car sales are way off, and even the mighty Japanese industrial machine is having a hard time clearing the docks of unsold vehicles.

The reason is patently simple: We just can't afford cars anymore. Interest rates, insurance, maintenance, replacement parts and the price of fuel all conspire to keep our wallets closed, and to make us keep our old cars running for a few more years.

Carmakers know this, and there are some bold plans afoot to change our very idea of the automobile. They want to entice us back into the showrooms, but not with flashy paint, killer-horsepower motors, outstanding handling or super-deluxe interiors. No way. The next-generation showroom traffic builders will be the automotive equivalent of the paper towel. Use it until it self-destructs and throw it away. This may sound obscene in a world growing short of natural resources, but hold your judgment until you hear the entire story.

The manufacturing process

Cars are being manufactured today just about the same way they were built back when Henry Ford created the assembly line. Robotics and automation have increased the efficiency of the assembly process, but the actual piecing together of the components and the components themselves have remained largely unchanged.

The process starts with metal stampings which are welded together to form the body. Usually this is done by automated or robotic

(Please turn to page 137)

New computer animation fools the eye

Expensive movie sets and special effects are being replaced by eye-catching, realistic-looking images generated by a computer.

by Neil Shapiro

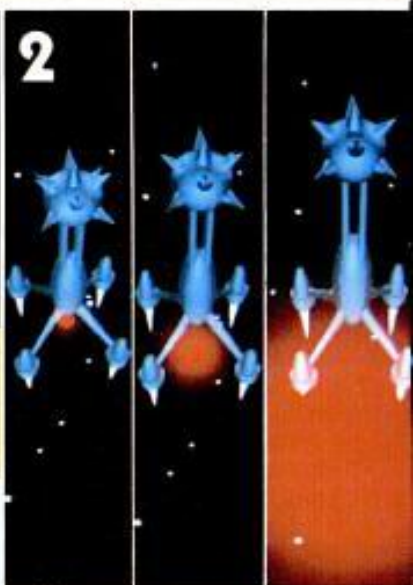
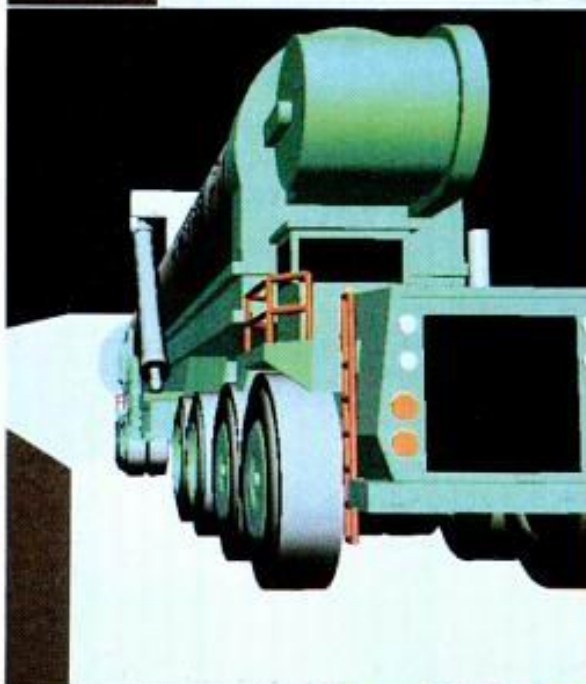
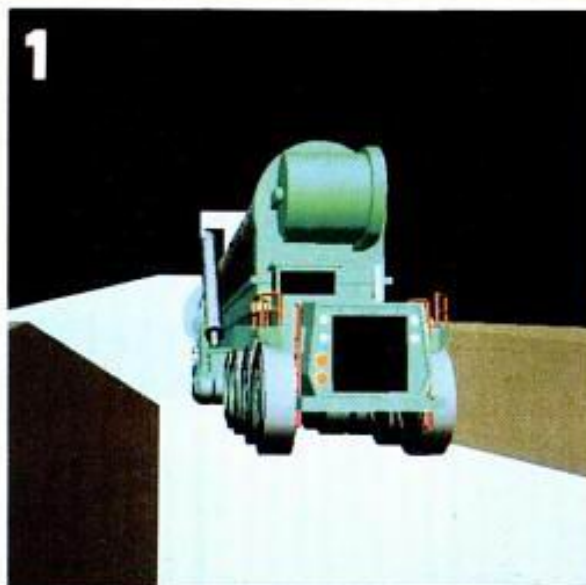
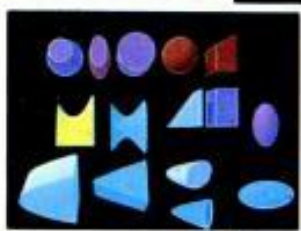
ELECTRONICS EDITOR

Bright, coruscating images spin across your TV screen. These fantastically detailed, animated images would take thousands of artist-hours to produce in old-fashioned, draw-every-frame animation studios.

But, today, new computer animators are cutting that time by more than 90 percent. And the animation can be done so well, so true to life, that many Hollywood studios are

(Please turn to page 108)

A programmer inputs primitives—building-block shapes, right, below—to computer.

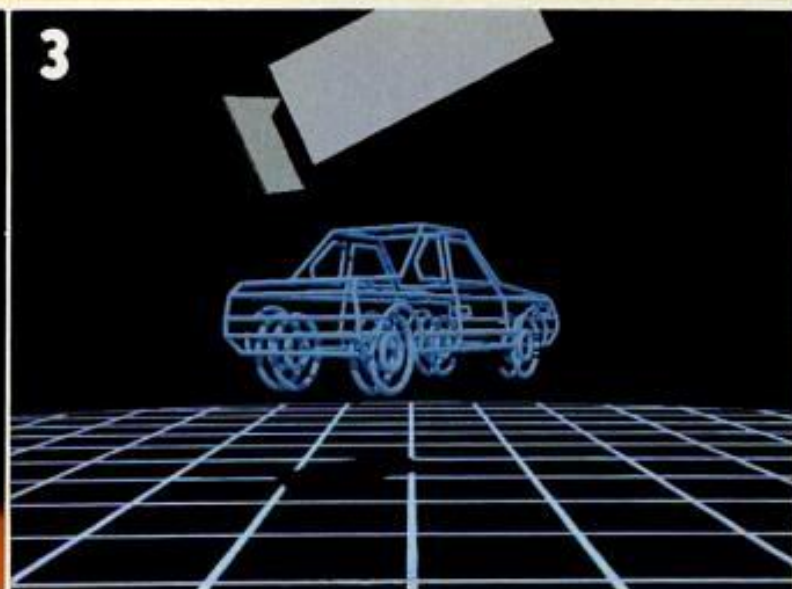
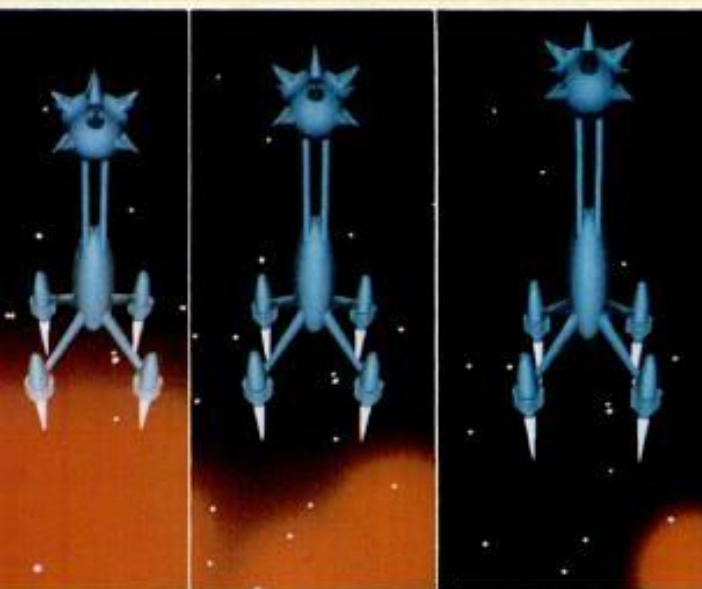


1 The truck sequence illustrates how the computer can zoom in on a complex figure to show great detail.

2 Movie studios looking for spaceships and other fantasy effects may soon turn to computer animation, instead of expensive models.

3 Here's a still from a TV commercial for recent auto shows in various cities. Animation sequence shows the car being packaged in the box floating above it.

4 Large picture shows the incredible resolution of detail computer is capable of. Picture is a conception of an undersea trawler.



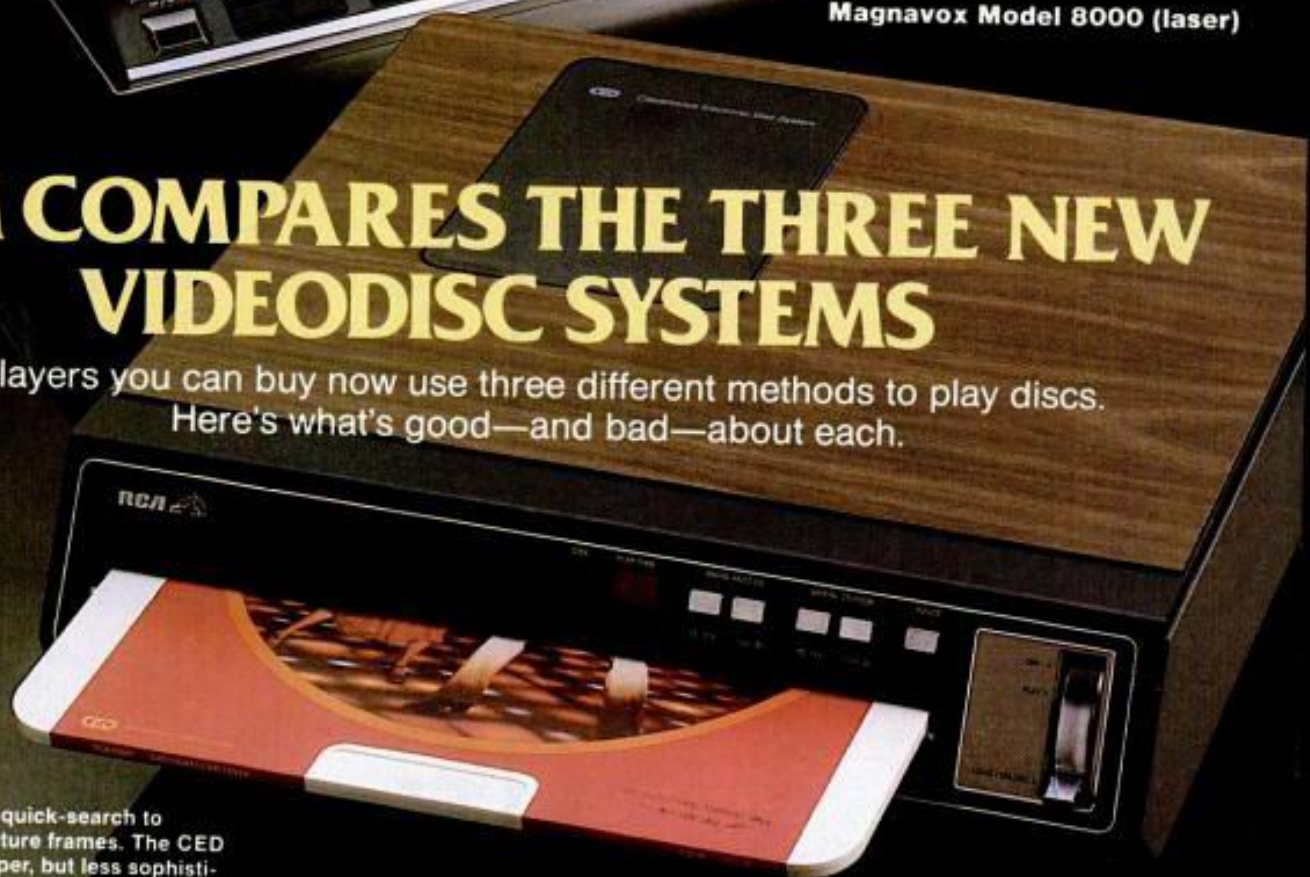


Magnavox Model 8000 (laser)

PM COMPARES THE THREE NEW VIDEO DISC SYSTEMS

Players you can buy now use three different methods to play discs. Here's what's good—and bad—about each.

Laser units offer quick-search to any of 54,000 picture frames. The CED players are cheaper, but less sophisticated. New VHD players combine some of the laser abilities with lower costs.



RCA SelectaVision Model SFT100 (CED)

SURF'N'

Amphibious cars are back—this time with high performance, sexy looks and clever technology.

BY CLIFF GROMER, Illustrations by Edwin Herder

When was the last time you pulled a waterskier—with your car? Civilian amphibious vehicles are nothing new, they've been around for over 100 years. Yet, while some have been able to kick up light dust on land, all have performed miserably slow in the water. The most well-known vehicle in this class, and the only one that was ever mass-produced, is the Amphicar. This German-made, sporty-looking convertible could be driven from the road right into the water, where its 43-hp engine could muster a top speed of only 7 mph. Heck, you'd become waterlogged before you could ski behind that.

Today, some 36 years after the last Amphicar rolled off the assembly line, there's a sudden

resurgence in recreational amphibious vehicles. No less than three fresh and viable designs are hitting the scene at about the same time. All address the biggest shortcomings of previous efforts: the tremendous drag of the wheels in the water and the inability to get up on plane.

Dobbertin HydroCar

The most radical-looking of the new amphi trio is the Dobbertin HydroCar. In 1990, designer Rick Dobbertin went from building pro-street machines to creating a huge amphibian called the Dobbertin Surface Orbiter. Beginning life as a stainless steel milk tank, the Orbiter covered 30,000 miles on land and 3000 miles at sea, traveling through 28 countries over a 3-year period.

TURE



The HydroCar prototype, currently under construction with completion expected this summer, is a 3-section tube-frame design that's covered in marine-grade aluminum. The center, or main, section supports the cockpit and midengine drivetrain. The two outer sections are sponsons that can move up and down in unison, independent of the main body. The sponsons are foam-filled for buoyancy, and are tied together on top through the main body by sponson supports and underneath the body by three hydrofoil wings that also provide lift. Eight airbags are mounted between the sponson supports and the main body structure—four bags above the supports and four underneath.

Inflating the four upper bags pushes the sponsons down 8 in. in relation to the body for the

water mode. Lowering the sponsons creates a tunnel-hull, or catamaran, configuration. Inflating the lower bags raises the sponsons for road use.

Eight additional airbags are mounted above and below the front and rear axles to raise and lower the wheels. In water, the wheels are pushed up into the sponson wheel wells. Plates then slide across the bottom of the wells to close them off and provide a smooth, continuous surface for the sponsons. On land, the airbags take the place of conventional springs. It's a setup commonly used by modern street rods. Switching from land to water mode, or vice versa, is said to take less than 5 seconds with the flip of a switch.

The HydroCar will not be wanting for power. A 502-cu.-in. Chevy V8 will see to that. The stout

HYDROCAR

engine is hooked to a GM automatic transmission and a transfer case for 2wd/4wd. There's also an in-out box, or electronic coupling, that connects the transfer-case shaft to the surface-drive prop. There's no power going to the rear wheels.

On landing, you shift into 4wd to drive the front wheels. Front-wheel drive, as opposed to rwd, is especially helpful when you're coming out of the water because the back end of the car may still be floating when your front wheels hit the ramp. On land, the in-out box interrupts power to the prop.

In the water, shifting into 2wd keeps the front wheels from turning while power is going to the rear to spin the prop. Pretty slick. The surface drive moves 40° to either side and functions as a rudder. It also can be raised to 40° to prevent you from skewering anyone on the highway. So what if motorists think you're driving some kind of mobile food processor. You'll have the last laugh in the flood plains.

Dobbertin expects the HydroCar to hit over 125 mph on land, over 50 mph on water, and about 150 grand in your



wallet. Check out his Web site at www.hydrocar.us.

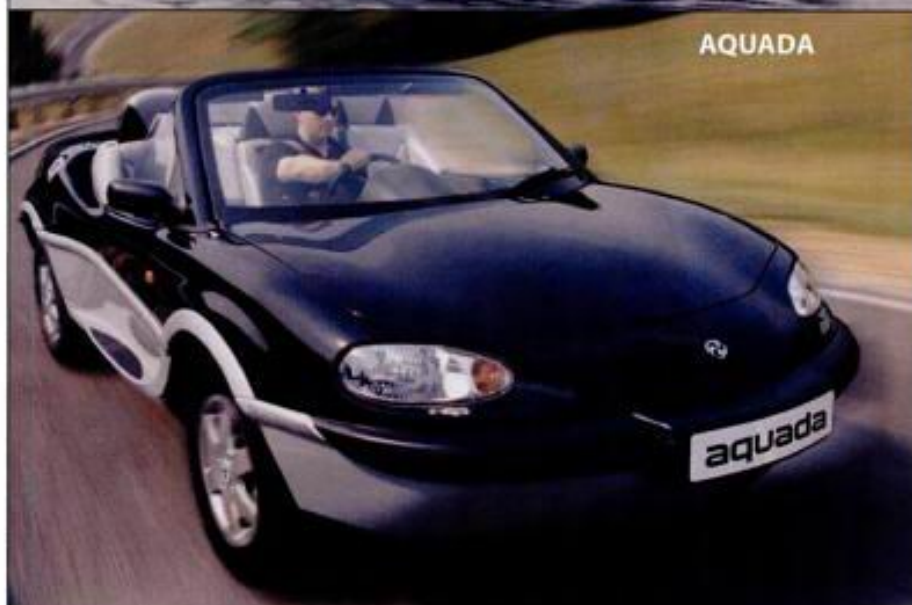
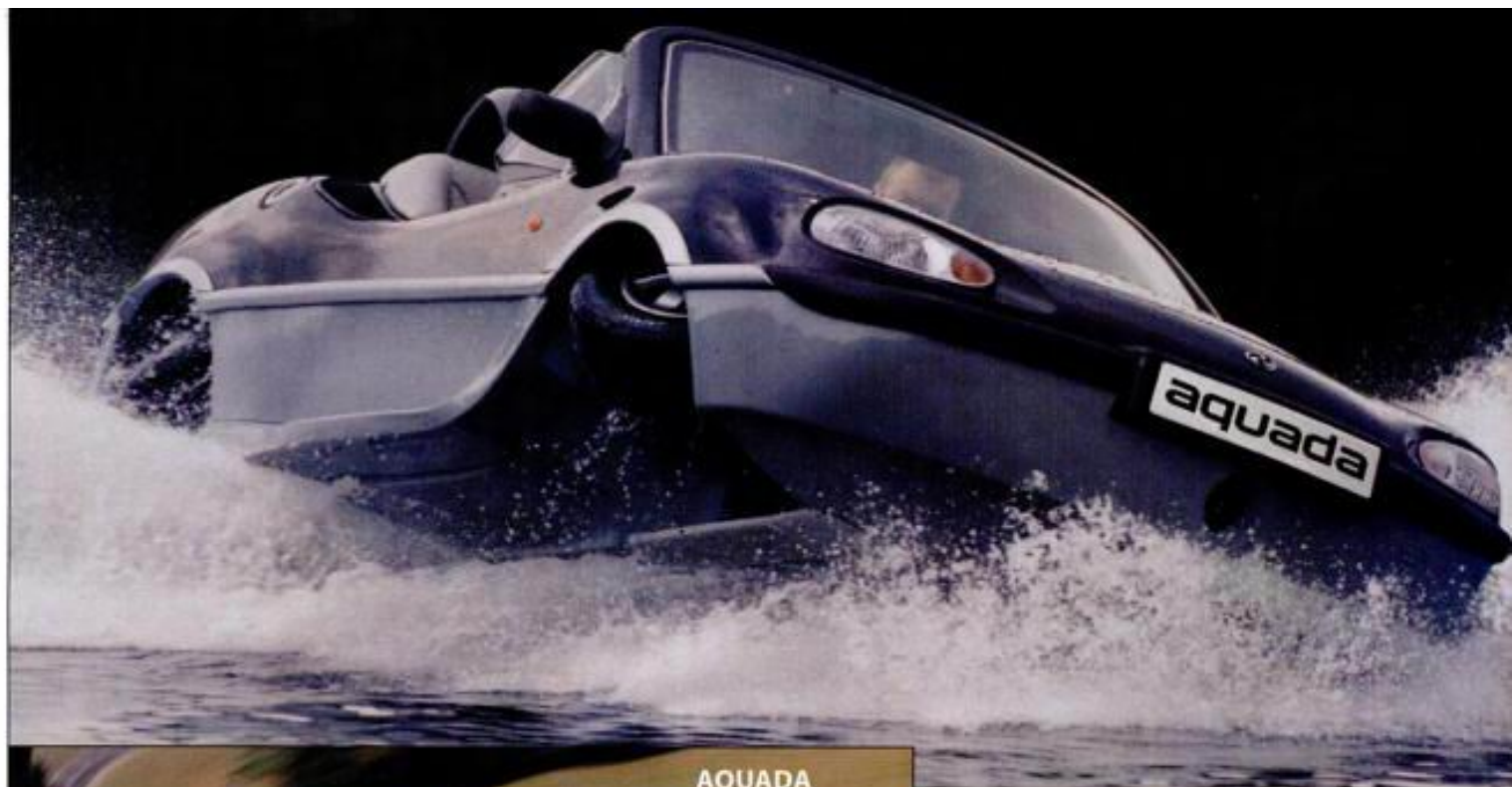
March WaterCar

If Dave March's WaterCar looks like a Camaro, it's because that's what it is. Sort of. The body is an off-the-shelf 2002-style Camaro funny car fiberglass shell. These come as flimsy, lightweight units with a hardtop, quarter panels, fenders, and no doors. It took a guy like March, with 20 years of autobody shop, car, boat and plane-building experience, to turn the shell into the 125-mph

The HydroCar wheel rises into the wheel well, shown with side cover removed (left). The well is not watertight.

(land)/45-mph (water) running prototype you see on page 66.

March extended the nose of the shell 8 in. to get a larger planing surface. He cut openings for the doors, removed the roof, and enlarged the wheel openings so the wheels could be pulled up 11 in. when in the water. The fact that the 4-seat Camaro body looks pretty much stock is a tribute to his bodywork skills. The doors seal with conventional automotive weatherstripping, and an aircraft-type handle and latch pull the door closed with more leverage than an automotive latch. The Amphicar had doors and, when aligned



properly, they didn't leak—as long as you didn't open them while you were on the water.

The WaterCar chassis is light-gauge 304 stainless steel square tubing that fits through channels fabricated into the shell. Because the shell had no bottom, March needed to create one out of fiberglass panels that he molded to shape. The bottom was limited to a fairly shallow V because of the Camaro's low stance. March says he has 3000 hours' work in the shell and bottom alone. The bottom configuration, with glassed-in wooden strakes, was a tedious process of trial and error.

The suspension is quite simple, as it was essentially lifted

from the stock 1986-1987 C4 Corvette. Coil-over shocks replace the Vette's composite spring. The wheel-bearing races are grooved so water-resistant grease can be shot in through a zerk fitting. With the rear-engine configuration, there was no need for the complexity of the stock power steering. Instead, a manual rack-and-pinion system was installed using aftermarket components from Flaming River.

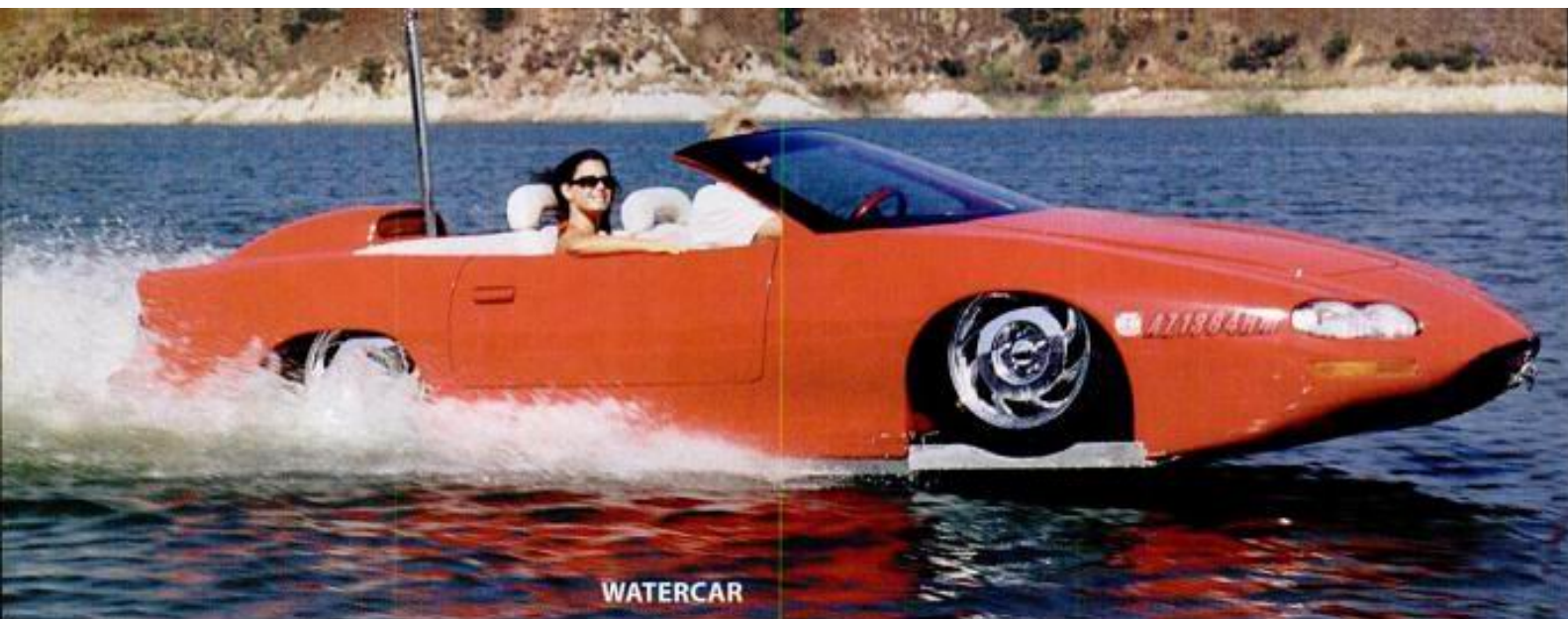
Getting the stock 17-in. Corvette wheels to go up and down was a simple matter, according to March. He added a bracket to the top shock mounts and used a 2-in. hydraulic ram to lift each coil-over unit along with

The Aquada has made the biggest splash to date, thanks to its media blitz. The car goes on sale in February in England.

the upper and lower control arm and wheel at each corner.

The choice of power for the WaterCar was inspired by the sand rails that line up to climb "Competition Hill" in March's home of El Centro, Calif. He noticed that the 2.5-liter Subaru WRX-powered rails were kicking sand all over those that were powered by Corvette LT-1 and Cadillac Northstar engines. March was able to fit the pancake-style "Volkswagen on steroids" Subaru engine and the rest of the drivetrain into the Camaro's trunk. The engine drives the rear wheels through a beefed-up Volkswagen Type 2-style transmission. On the water, the engine drives a Berkeley jet pump. The key to the system is a custom-built transfer case designed by March that engages either the wheels or the pump, or both at once—using both is the way to go when driving out of the water.

March is taking orders for the WaterCar on his Web site, www.watercar.com. The price is about \$150,000. March's future plans call for a lower-priced



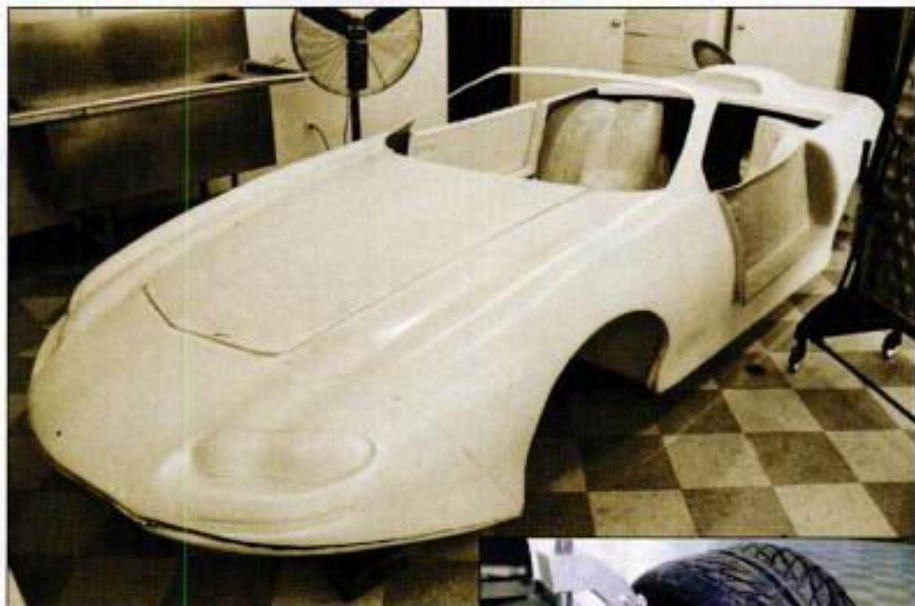
WATERCAR

SUV version in the \$80,000 to \$100,000 range.

Gibbs Aquada

The Aquada from Gibbs Technologies of Warwickshire, England, is the furthest along in development of the current amphibious offerings. The first wave of these British-built car-boats is scheduled to roll (float?) off the production line this February. Aquadas numbered 1 to 100 will be called the Bond (as in James) Series, and they reportedly will zip along at 110 mph on land and 35 mph in the wet. The going price for the Aquada in England is about \$250,000, and company co-owner Alan Gibbs says 20 of them already have been sold. The United States isn't expected to see these amphibians crawling onto its shores for at least another two years.

Virtually all the components in the 3-seat Aquada, save the 175-hp 2.5-liter Land Rover Freelander V6 engine and the Jatco 5-speed automatic transmission, were designed by Gibbs. Building the vehicle from scratch, as opposed to using off-the-shelf hardware, obviously adds to the cost. The composite body has no doors—this measure was taken to ensure a watertight compartment. That's interesting considering the Amphicar and WaterCar seem to have no problem with watertight door sealing. To



The WaterCar uses a hydraulic ram to raise the Corvette wheel (above). Note the coil-over suspension. The entire drivetrain fits in the trunk (left).



enter and exit the Aquada, it's yo-ho! Over the side, matey—except for those with arthritic or rickety hip joints. The car's body is glued to the square-tube aluminum chassis.

On land, the Aquada is driven by the rear wheels. A second axle powers a jet pump that delivers 2200 pounds of thrust for water use. Gibbs had to design this pump because there was not one available that could deliver this level of performance in the required compact-size package.

In general, compared to American-engineered automotive products, the British seem to favor complexity over simplicity of design. In addition to the separate axle shaft for the jet pump, the Aquada has dual cooling systems—a conventional air-cooled radiator for the landlubbing mode and a separate water-cooled heat exchanger for when you don your captain's cap.

Switching from car to boat mode requires just 5 seconds with the press of a button, and the transition in operation is seamless. Built-in safety features prevent the transformation from taking place until the on-board computer determines that it's appropriate to do so. Ride-height sensors must indicate that all the wheels are at full drop, and other sensors must detect the presence of water in the jet.

Remember The Amphicar?



When you think of a civilian amphibious car, we bet that just one nameplate comes to mind: Amphicar. Some 3878 copies (90 percent of which were exported to the States) of this German-built surf 'n' turfer were built between 1961 and 1968, making it the only car of its ilk to see mass production. The Amphicar was powered by a British-built Triumph Herald 43-hp engine coupled to a 2-part transmission—a Porsche-built Hermes 4-speed transmission for land, and a single forward and reverse gearbox, with twin nylon props, for use on water. Top speed was 70 mph on land and 7 mph on water. When new, the vehicles sold for between \$2800 and \$3300, depending on model year.

—C.G.

Gibbs says he drives the Aquada into the Thames at 25 mph. When the water reaches a sufficient depth, a number of things happen simultaneously. The wheels fold into the wheel wells and the steering rods are articulated, which allows the steering to be disabled. The power steering is used to control the direction of the jet pump.

Trim tabs are set automatically to the correct angle for takeoff, and the rear axles are disabled.

For More Outdoors Features
Check the PM.Zone Web site at
popularmechanics.com/outdoors

Each halfshaft going to the rear wheels incorporates a hydraulically operated clutch, which is disengaged in the water and engaged for power delivery to the wheels when on land. Gibbs says that 5 seconds into the water mode, the Aquada is on plane and zooming down the Thames toward London (while he waves to motorists bogged down in traffic). And while they're waiting, if they have a wireless connection to the Internet, they can check out the Aquada Web site: www.aquada.co.uk.

Cheers!

FM

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JANUARY 2004

Popular Mechanics

**BEST OF
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Technology

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C-130 Transport Goes Vertical

An idea drawn from the early days of commercial aviation may help the Army solve its chief 21st century logistics problem: getting materiel inside hostile terrain without diverting troops to protect supply lines.

Responding to a request from the Defense Advanced Research Projects Agency, Groen Brothers

Aviation of Salt Lake City, Utah, has devised a way to turn a standard Lockheed Martin C-130 cargo plane into an aerial delivery truck. The converted aircraft could take off and land like a helicopter, then sprint out of harm's way at 300-mph speeds.

Converting a C-130 into what Groen calls a Gyrolifter would require altering

the airplane's tail assembly and adding a 5-blade rotor, as shown here.

During takeoffs, landings and while hovering, the rotor would be spun by jets placed in aerodynamic fairings on the tips of the rotor blades. Once at a safe altitude, the rotor would freewheel and the Gyrolifter would rely on the C-130's engines.

Inside, the cargo bay would remain relatively unchanged, enabling the Gyrolifter to step in as a direct replacement for the C-130 with minimal crew retraining. If the Pentagon says yes, the first Gyrolifters could be flying by 2008.

Editor: Jim Wilson
Reporters: Stefano Coledan, Mike Fillon, Scott Gourley, Paul Ruben.

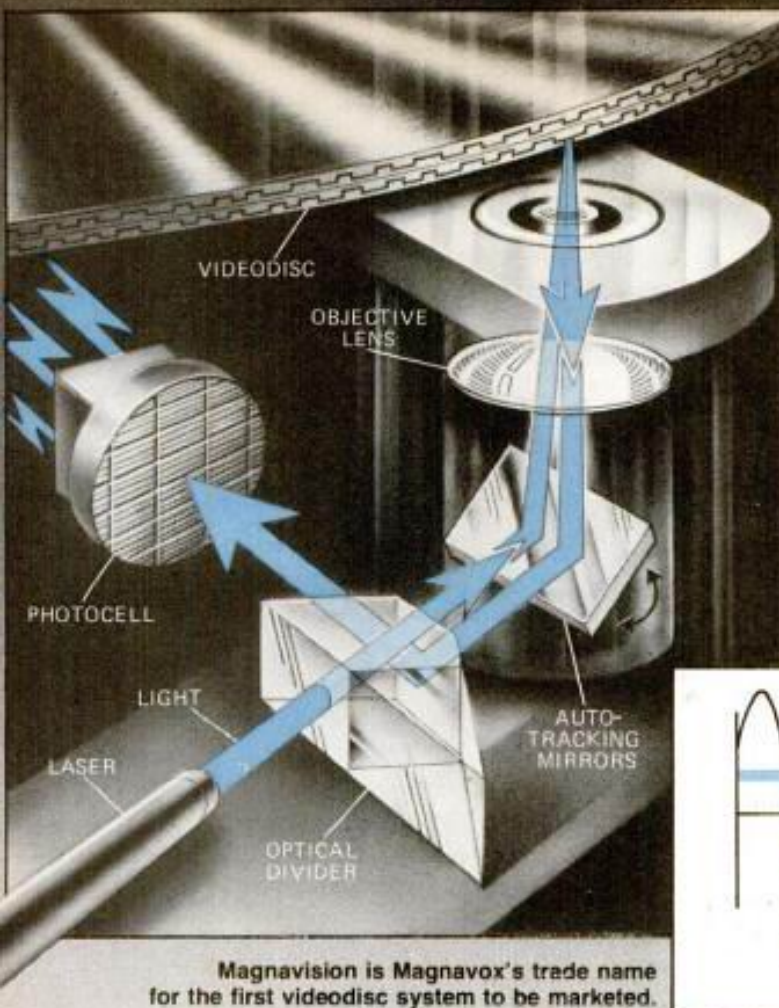
The videodisc player offers many conveniences as shown here (top). You can return to the same scene over and over, fast-forward or reverse, even freeze-frame. The only thing you cannot do is record. Playing a prerecorded disc (bottom) is simply a matter of closing the lid and hitting play.



PM's complete guide to the NEW VIDEODISCS and CASSETTES



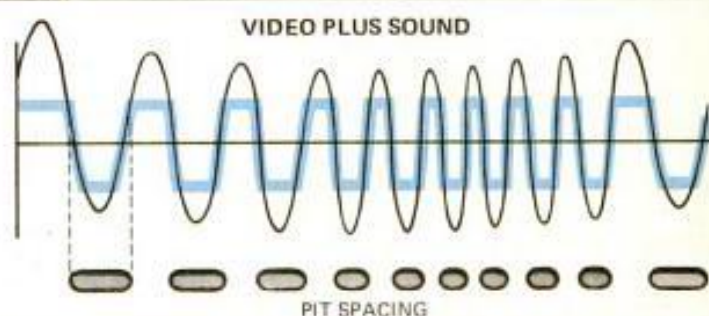
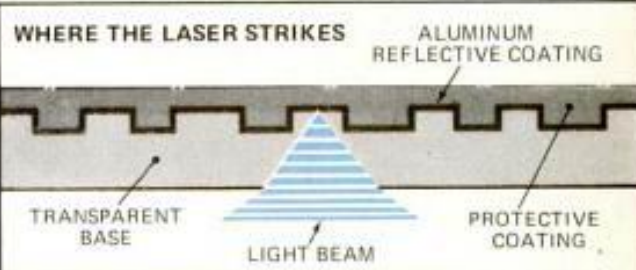
PM Photos: Frank Lusk



Magnavision is Magnavox's trade name for the first videodisc system to be marketed.

MAGNAVISION VIDEODISC SYSTEM

First videodisc system is Magnavision from Magnavox. It uses a laser to "read" digitally encoded discs. Laser light is focused, from below, on the spinning disc. The beam of light passes through a transparent base material which protects disc from fingerprints. It then hits optical pits on a reflective aluminum surface (backed up by a further protective coating). Light bounces back, changed by reflecting from the pits. Information contained in optical pits is further enhanced by spacing of the pits along a spiral track. Video and sound are both so encoded.



Choosing between one of the new videodiscs or video cassettes can be confusing. Here's what's available now—and what the near future holds in store.

by Stan Prentiss

The videodisc is out to challenge the more familiar video cassette recorder/player. At least four companies, by the middle of next year, will offer new disc systems, each slightly or significantly different from the rest.

Conflict in the marketplace results from one simple fact: Video cassettes can record and play back off a home television or, with an accessory camera, can even take home TV "movies." Videodiscs *cannot* record; they only play back previously recorded movies or programs from discs reminiscent of stereo records—but the discs cost less than tapes.

Magnavox is first on the market with its silvery-plattered Magnavision disc system. Production has been currently sold out in test markets, such as Atlanta and Seattle.

Priced at \$695, Magnavision operates on a laser-light system. The disc contains digitally encoded information "read" by the laser. There are

rows of optical pits along the surface of the disc. A laser beam, focused from underneath the spinning platter, is bounced back, changed by the manner in which the pits have reflected it. It is this change which carries the information as to what the TV picture should be.

The disc is protected from fingerprints and other damage by a plastic coating. The discs are also aluminum-backed, so that they have a

startling, rainbow-like appearance.

The videodisc can hook up to any TV right at the antenna terminals. Audio output is on two separate channels which are, of course, combined by most nonstereo TVs. Future possibilities would include such things as stereo or bilingual sound tracks.

Each side of a Magnavision disc has a 30-minute playing time. Right now Magnavision offers such fea-



You can team Quasar's VH5200 portable with its VA515 varactor tuner. This would give you microprocessor control, along with remote channel changing.

tures as fast forward and fast reverse, as well as slow motion in either direction. Each disc side can hold 54,000 frames. Every one of these frames has a reference or index number which can be displayed—and each frame can be frozen still. If you want to direct someone who has a videodisc to a favorite movie scene you could say, "Pull out frame 40,167 in *Casablanca*" and know exactly what he or she would see. Right now it requires fast forwarding and reversing to get to the right frame. In the future, the viewer will likely have immediate access to any single frame.

RCA is jockeying to have its own videodisc—a capacitance-stylus system—ready later this year. But informed sources do not expect to see it until 1980. The system has a diamond needle that will ride in grooves on the disc itself. It will measure the difference in electrical charge potential (capacitance).

The RCA system as yet has no capability for freeze-motion, and no slow or fast motion—only normal playing speed. It is somewhat subject to wear on both needle and disc, while a laser system (like Magnavision) has a life expectancy of at least 5000 hours of playing time.

One very important thing about the RCA system: It will likely be cheaper than its laser competition—somewhere in the \$400 to \$500 range.

Panasonic (as reported in last month's *PM Electronics Monitor* column) is currently considering a quartz needle pickup. The system would use the piezoelectric property of quartz (changing vibrations from the grooves into electrical voltage). The disc would be 9 inches in diame-



Video cassettes, such as this PV-1600 from Panasonic, point up differences between disc and cassette. As shown, this deck can use different video cameras to record home video "movies." It can also record off the air. Discs are play only.



ter and also subject to wear from the needle.

JVC (Victor of Japan) is reputed to have a highly versatile videodisc system waiting in the wings. It is a needle-type system, but is said to have "electronic grooves" so the needle won't contact the record.

Pioneer is the only company besides Magnavox that—at press time—has a videodisc system actually on the market. Pioneer's is a laser system similar to Magnavox's although discs are not interchangeable from one system to the other.

Pioneer has yet to enter the consumer field with its videodisc, but it has already sold at least 7000 systems to General Motors. The units feature all the goodies, including stop-frame indexing and slow and fast speeds. They cost about \$3000 apiece and come equipped with Zenith TVs and a big cabinet.

They will be used in promotional campaigns at the dealer level. Whether Pioneer intends to get the price down and sell to the consumer is yet to be seen.

On the cassette front

Things have not been standing still with the video cassette. The disc may threaten it, but since the disc cannot record, most see the cassette continuing for a long time to come.

What is new this year for these tape player/recorders is primarily extended playing time, some additional programming abilities and the introduction of *portables* (with both manual and electronic tuners) that can record or play for 30 to 80 minutes.

Less expensive table models feature mechanical tuners and single-channel programming, while their more expensive cousins have deluxe



Sony's SL-3000 is a portable video cassette that can team up with any Sony video camera. You can take it along, no matter where you go, for on-scene action.

PM TECHNOLOGY UPDATE 12/86



Future Rocket Will Make 'Local' Stops

Current space vehicles, including the Space Shuttle, are designed to take satellites to a specified orbit. But the Air Force has awarded to Hughes Aircraft Co. a contract to design and build an expendable launch vehicle that deposits satellites at different orbits on the same flight.

The Jarvis Medium Launch Vehicle (MLV) could

carry six satellites to orbits ranging from low-earth to geostationary. The MLV is named for Hughes engineer Gregory B. Jarvis, who was killed in last January's *Challenger* explosion.

Working with Boeing Aerospace, Hughes plans to design the system around the Saturn booster, the same powerplant used by the Apollo moon launch project.

Some elements of the rocketry used in the Space Shuttle may find their way into the Jarvis system.

As envisioned by Hughes, the rocket will stand more than 20 stories tall with a payload bay 6 ft. wider than a 747 Jumbo Jet passenger compartment. The nose-cone section will have its own propulsion system and will open like flower petals,

PM's conception of the Jarvis rocket shows powered nose cone releasing payloads at different orbits along flight path.

mechanically casting off satellites as it passes through different orbits. The Jarvis MLV should be ready for duty in the 1990s.

Editor: Dennis Eskow
Contributors: Michael Filion, Richard Schrader, Doug Dreys, Steve Eskow

FOUR WAYS TO Portable Computing Power

No matter where you go, your computer can be alongside. Here are four that make the computer revolution a movable feast.

BY HERB FRIEDMAN

KAYPRO II



RCA VP-3501



Virtually unknown just a few years ago, the portable computer is fast becoming a success story. Though relatively light and compact, various models offer many of the features and performance of "full-size" desktop computers, yet they are small enough to fit under airline seats, be carried in a shoulder bag, or even slip into a standard attaché case. You can take them along on business trips and vacations, or on the daily commuter train. They can be set up quickly on the kitchen table, in a motel room, or even on your lap.

Our four computers are the Osborne 1, the KayPro II, the Epson HX-20 and the RCA VP-3501. (The RCA VP-3501 isn't really a computer, it's actually a videotex

terminal which provides the user with computer and database services through information networks such as The Source and Dow Jones. But, in a sense, the RCA terminal serves as a "portable computer" because it can access computer and information services through the nearest telephone.)

The Osborne 1 is the model that introduced a wholly new concept in portable computing: that of a full-featured computer in a relatively light, easily carried cabinet. It is housed in a plastic cabinet that measures 5 in. wide x 13 in. deep x 9 in. high, and weighs under 24 pounds. Features include: 64K of RAM (memory), a built-in video monitor; an output for a dedicated communications modem (to send and receive data over a phone); an

Osborne 1 was the first of the portable computers and is still one of the top contenders. Complete with two disk drives and small screen, it arrives with a full software selection. KayPro II is similar in concept to the Osborne but has larger screen. It, too, comes with an impressive software collection. The Epson HX-20 can be carried in your attaché case. Its liquid-crystal display (LCD) makes the unit truly portable. The RCA VP-3501 isn't a computer—it's a terminal. Hooked up to a TV and phone, it accesses large computers.

OSBORNE 1



EPSON HX-20



PM photos: Lou Javitz



KayPro II's keyboard features all the keys found on a full-sized computer, including a numeric keypad (above). It all folds together into a portable, easy-to-set-up package (right).

RS-232C serial I/O (input/output) for a printer or a communications modem; an IEEE I/O which also provides a Centronics-type printer output; an output for an optional, large, external video monitor; a connector for an optional, external battery power supply; two 5¼-in. floppy disk drives, each providing approximately 100K or 200K bytes of storage (depending on whether you purchase the single- or double-density computer model). The single-density model costs \$1,795 (and might no longer be in production although still available in stores). The double-density model is priced at \$1,995.

The Osborne 1 keyboard is part of the cabinet cover. It can be detached and placed about a foot from the computer. Just about everything else is on the main cabinet's front panel. A disk drive is positioned on each side of the panel and between the disk drives is a 2.6 in. × 3.5 in. video screen with a display 52 characters wide by 24 lines. Across the bottom of the panel are the battery power, external video, peripheral and accessory connectors, computer reset switch, and video brightness and contrast controls.

What really creates enthusiasm for the Osborne 1 is the supplied software package—its retail worth is almost equal to the cost of the computer. It consists of the CP/M disk operating system, MBASIC (MicroSoft BASIC), CBASIC (Compiler BASIC), WordStar (perhaps the most famous word processor), MailMerge (which does form letters) and SuperCalc (an electronic spreadsheet system). A special promotion deal also included dBase II, a rather expensive data management system.

In particular, the CP/M implementation for the double-density model is superb; it's many times more convenient than the standard CP/M implementation used in the old single-density model. The double-density CP/M is entry-level-user and applications-oriented—so simple even a child

would have no difficulty—truly "user-friendly."

However,

Wordstar is almost a programming language in itself, with 149 individual command and formatting codes. While extremely powerful and flexible, it is somewhat difficult for the casual user to learn and use. The problem is compounded by the Osborne's 52-character video screen, which makes it extremely difficult to use the on-screen "help" menus that extend well beyond 52 characters, and which are important for the casual user. Also, since most business letters and documents are normally 60 to 64 characters wide, the user cannot see the actual document formatting on



RCA's VP-3501 is a videotex terminal which has no built-in computing power of its own. Instead, it connects via a telephone to computer networks or other computers and uses any television for display.

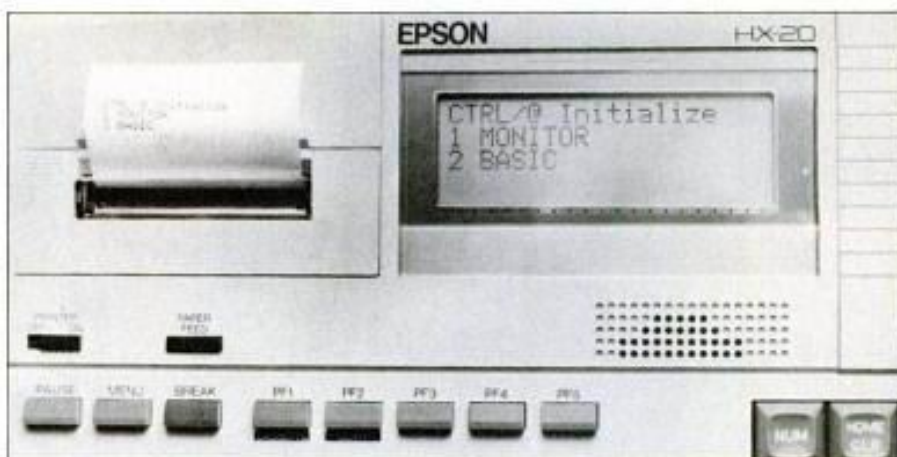
the Osborne's screen. While the Osborne's screen does a horizontal scroll if the user types beyond 52 characters, it's not the most convenient system to use if you want to search for something normally "off the screen."

But for those who want maximum convenience and flexibility in word processing, Osborne has an optional upgrade that provides an 80-character display. While 80 characters on the small, internal screen is almost illegible, it appears "normal" on a larger, plug-in monitor. The 80-character screen also makes *SuperCalc* (perhaps the most user-friendly Calc-type program there is) even better, as it adds at least three additional columns to the display.

A serious inconvenience that can affect the Osborne's use in an office or other "permanent" area is the location of the connections along the bottom of the front panel. The cables come out right on the keyboard, or they interfere with loading the left disk drive or viewing the screen. For those who have their printer or modem connected at all times, it's an important point to consider.

Big and bright

The KayPro II portable computer is similar in external appearance to the Osborne, and also comes with 64K of RAM. It is housed in a metal cabinet



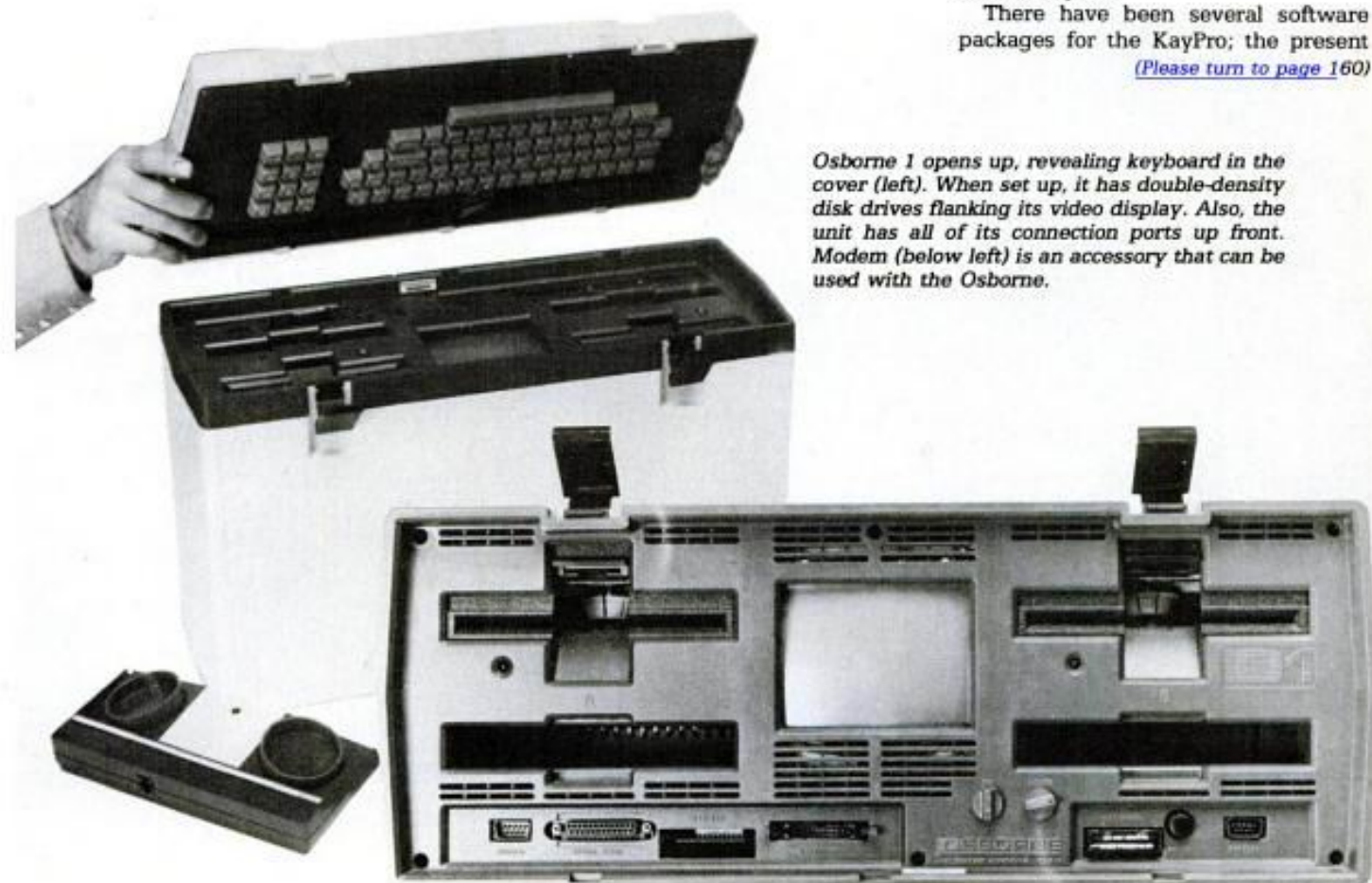
Epson HX-20 is an attaché-case-sized computer with features such as a built-in LOD display, a printer and a row of user-defined function keys, all shown above.

that weighs about 25 pounds. Overall, it's 18 in. wide $\times$ 16.3 in. deep $\times$ 8 in. high. The front cover is also the keyboard; it connects to the back of the main cabinet through the same type of coil cord used for modern modular telephones. On the back of the cabinet is the carrying handle, posts for wrapping the attached power cord, connectors for all standard printers, a video brightness control and the computer's reset switch.

Although externally similar to the Osborne, the KayPro II takes a somewhat different approach to portable computing. First, it is available only

in its latest version, which is double-density, providing approximately 200K bytes of storage on each of two 5¼-in. disk drives. The price is \$1,795. Second, and more important, it has a 9-inch, razor-sharp, 80-character, 24-line video display that takes up almost the entire left half of the main cabinet's front panel. (The two disk drives take up the entire right side.) Since 80 characters by 24 lines is considered "standard business" width for personal computers, all software provided with the computer—and virtually all you might purchase—will deliver optimum display on the KayPro.

There have been several software packages for the KayPro; the present [\(Please turn to page 160\)](#)



Osborne 1 opens up, revealing keyboard in the cover (left). When set up, it has double-density disk drives flanking its video display. Also, the unit has all of its connection ports up front. Modem (below left) is an accessory that can be used with the Osborne.

A man in a light blue button-down shirt is shown from the chest up. He is wearing a headset with a microphone. He is holding a large, black, rectangular electronic device in his right hand. This device has a small screen at the top displaying '1380.9' and '17'. Below the screen are various buttons and a small dial. The brand name 'SEIKO' is visible on the device. Two cables are plugged into the top of the device. On his left wrist, he is wearing a wristwatch with a similar liquid crystal screen showing '1380.9' and '17'. The watch has a silver-colored metal link band. The background is a plain, light-colored wall.

WATCHES

More Than A Good Time!

Today's marvelous watches let you watch TV, win sports car rallies and translate foreign languages. They even keep great time.

BY NEIL SHAPIRO ELECTRONICS EDITOR

Remember when watches had a big hand and a little hand and all they did was tell you the time? Well, today's electronic watches, with their sleek, liquid crystal displays and computerized innards, go much further than that. Telling the time is a sidelight now—sort of icing on the programmed cake.

Today's watches can do a lot more than tell you the right time. If you're an active person, they can do quite a bit to enhance your lifestyle. Now, we don't know anybody who actually owns *all* of these types of watches. But, if you will permit us a bit of whimsy,

SEIKO TV WATCH
(And FM Receiver)

PM photos: Bill Ashe

A wristwatch you can watch on your wrist may be in the near future. Seiko has unveiled its revolutionary new TV watch with a liquid crystal screen. The picture is clear and easy to see.

MARCEL 757
(FM Stereo)

CASIO TE-2500
(Dictionary)

EDMUND 33,164
(Budget Calculator)

SEIKO MGL03
(Sports Timer)

"Get down" with a stereo watch and headphones (above), or get the word with an English-foreign language dictionary watch (right).

follow us while we detail an evening in the life of the mythical Thomas Tock, man about town and watch owner extraordinaire.

Stepping out

Tock, both his arms covered from wrists to biceps with the latest in programmed technology, is alerted to the evening's revels by the first of many insistent alarm beepings. Practiced eyes glance down the row of watches on his left arm.

Dexterously resetting the Marcel (Model 750) multi-alarm, dual-time

zone watch, Tock sets out for a night on the town.

Sensing that he's making good time driving through the late-night traffic, Tock glances at his Seiko Tachymeter Sports 100 (Model MGL03) to check his average speed and estimated time of arrival.

Barreling through a sharp lefthander, Tock notices that the Seiko's tilted face allows him to keep both hands firmly on his silver Porsche's steering wheel. Finally, Tock pulls up in front of his favorite disco.

At the bar, he's amazed to find that

Be a sport and wear a watch like this Sports Timer (above), which will time all of your favorite sporting events. Or be a stay-at-home and calculate all of your household finances on this aptly named Budget Watch (top).



Now you can have entertainment on your wrist. In the roulette game watch, the wheel spins and realistically slows. Kopy Kat game watch is a rendition of the match-the-musical-note games. You can take on aliens in Star Trek's Wrath Of Khan. Or get closer to Earth and maneuver your tank away from attacking airplanes.



Casio's touch-sensitive face will make you wonder where the buttons went. Other calculator watches, such as the Armitron and Marcel, feature tiny but easily pressed buttons. Some calculator watches, such as Armitron and NSC models, include countdown timing functions.

the bartender doesn't know how to make a Martian Wallbanger. Luckily, Tock's Edmund memo watch (catalog No. 33,217) saves the day. The watch's one-line display scrolls the list of ingredients in a manner reminiscent of the old Times Square marquee.

As the drink arrives, our hero cannot help but notice the dark-haired, sultry beauty who seats herself next to him. They turn to each other and she smiles and says something to Tock. After a moment of puzzlement, he realizes that she is speaking a different language.

The Casio Dictionary watch (TE-2500), worn high on his right arm, comes to Tock's rescue. Its Spanish-English and English-Spanish functions soon have Tommy and Estralita chatting—via his watch face—like old friends. Both, they find, are electronic game players.

With a flourish, Tommy unveils his Mercury Plane/Tank electronic game watch (3655) and it isn't long before the two together have saved well over a platoon of heavy tanks from being ravaged by dive-bombing enemies.

Near closing, the bartender presents Tock with the tab. Tommy nonchalantly picks up the itemized bill and clicks on the calculator display of his Casio touch-sensitive calculator watch (TC-500). The face clears to a flat display of calculator buttons. The heat-sensitive sections of the watch's face respond to his darting fingertips as he calculates the bill. He sighs. There's been no error and he reaches for his wallet.

His monetary problems fade as he enters the lovely Estralita's phone num-

ber and address into the two-line display of his Seiko memory watch (MGJ07M).

His pulse pounding (he checks this with his Edmund pulse watch, catalog No. 33,160), he offers Estralita the chance to accompany him home to see his etchings of rare old timepieces.

She smiles sadly. No, she sighs, and tells our man of the hour that she fears she has come down with a cold.

A quick check with the Casio temperature watch (TS-1000) confirms this fear. Not even Tommy's exciting presence could generate that high bar-graphed reading.

Before leaving, alone, he checks his blood alcohol level on the disco's wall-mounted breath analyzer (that one's not yet built into a wristwatch). It's okay. He pulls out his car keys

(Please turn to page 126)



TIMEX 67731
(Sports Timer)

You can time individual laps with this sports timer watch (also available in men's version).

SEIKO MGM05M
(Rallye Timer)

Drivers will get super-charged performance and function out of this special timer watch.

EDMUND 33,218
(Jogger's Watch)

Joggers can set the pace with this watch and keep track of how far they run.



EDMUND 33,217
(Memo)

Keep a phone number handy with this watch and its one-line scrolling display.

SEIKO MGJ07M
(Memo)

A two-line display and calculator functions make this a real thanks-for-the-memory watch.

MARCEL 731
(Memo)

Scrolling memory display keeps track of events. Shoot-'em-up game helps pass time.



MARCEL 750
(Multi-Alarm)

Many watches feature multiple alarms. With a watch like this, you can beep day and night.

EDMUND 33,160
(Pulse Watch)

Ever want to take your pulse on the spur of the moment? This watch will do it for you.

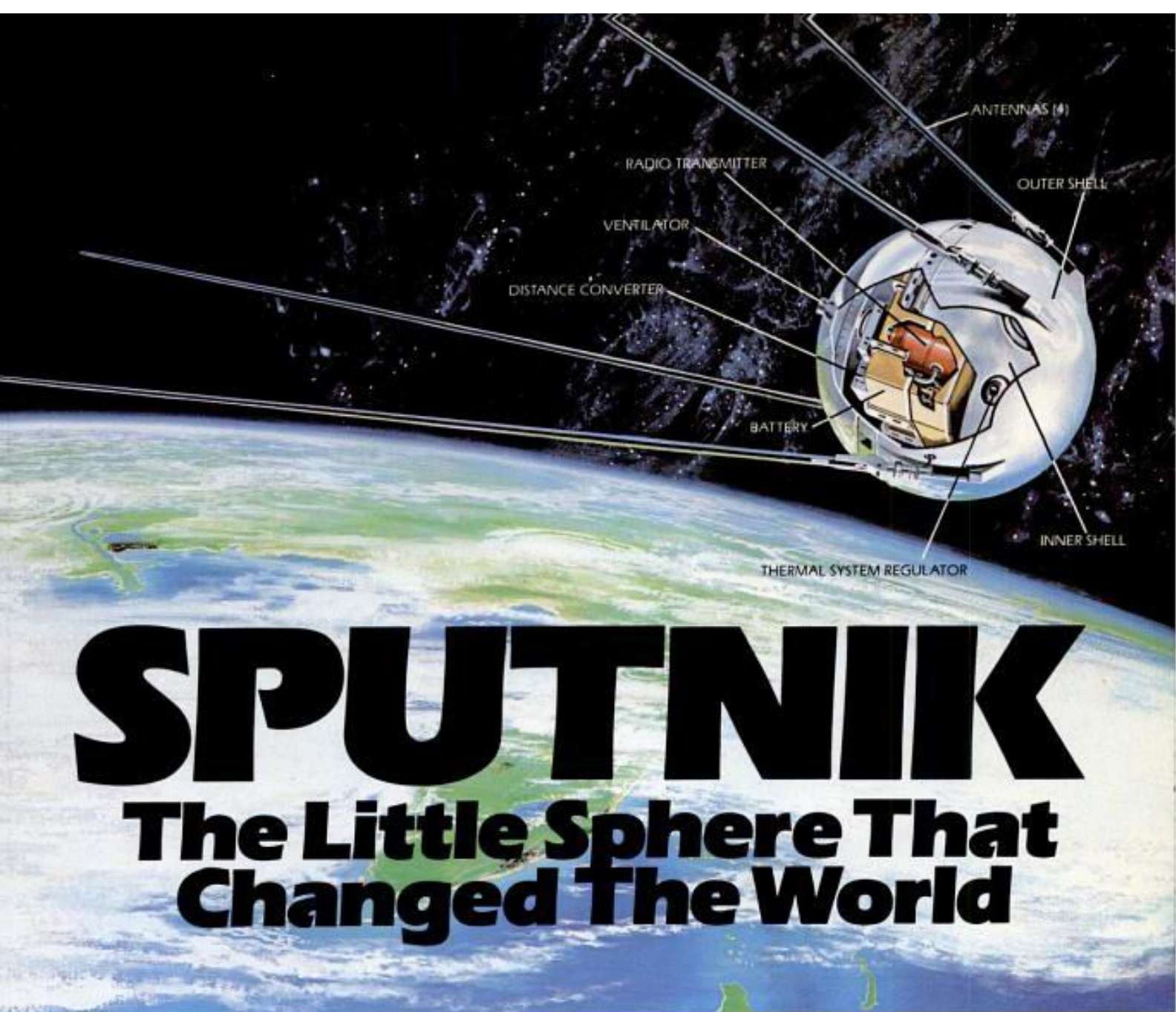
CASIO TS-1000
(Temperature Watch)

This watch will keep track of your body temperature as well as your appointments.



ARMITRON 40/6351 (FM Stereo)

This FM stereo watch features an on-the-face tuning control, in addition to a power supply and headphones (not shown).



SPUTNIK

The Little Sphere That Changed The World

Early in the evening of October 4, 1957, an American clinked the side of a glass, silencing the reception room at the Soviet Embassy in Washington, D.C. Geophysicist Lloyd Berkner faced an elite crowd of scientists who had been discussing plans for launching rockets and satellites to study the Earth.

"I wish to make an announcement," Berkner said. "I am informed by *The New York Times* that a satellite is in orbit at an elevation of 900 kilometers."

No one had ever heard such news before. But the real shock came in the rest of Berkner's short speech. "I wish to congratulate our Soviet colleagues on their achievement."

As a satellite, *Sputnik I* was little more than a bulky thermometer attached to a simple radio transmitter. It carried no sophisticated instruments. Much of the interior space inside a sealed aluminum casing 22.8 in. in diameter was taken up with chemical batteries, bathed in gaseous nitrogen, powering the

Thirty years ago this month, a tiny silver orb launched from the Soviet Union signaled man's introduction to the Cosmos. Today, satellites affect nearly every aspect of modern living—from improved communications to managing Earth's resources.

BY GURNEY WILLIAMS III
PM Illustrations by Dean Ellis

A battery, a thermometer, a transmitter—*Sputnik* had no real scientific value. But it did move man's thinking beyond Earthly confines.

2-frequency radio. The radio quit in little more than three weeks. The satellite stayed up for just 92 days.

But the successful orbiting of the Soviet sphere changed the course of American history in ways that could be appreciated only in later years. The Soviet RD-107 rocket that launched *Sputnik* illuminated our ignorance, and launched us into a fearful, heady flight to catch up. It spawned dozens of UFO reports, and melodramatic fights over who owned the new territory of space. The Soviet feat boosted the political fortunes of a 49-year-old Texas senator named Lyndon Johnson.

Long before "Star Wars," it fueled a young and secret movement of military experts urging President Dwight D. Eisenhower to develop a defensive shield against a Soviet missile attack. And it set off a little-known search for an American satellite strong enough to survive a wild ride atop a prototype, intermediate-range ballistic missile.

REVOLUTION IN SPACE

A catalog of some of man's most significant achievements in satellite technology.



TELSTAR I
7/10/62
FIRST ACTIVE COMMUNICATIONS SATELLITE



TIROS I
4/1/60
FIRST WEATHER BUREAU SATELLITE



SYNCOM II
8/28/63
FIRST SATELLITE IN GEOSYNCHRONOUS ORBIT



ERTS (LANDSAT I)
7/23/72
FIRST EARTH RESOURCES SATELLITE



ORBITING ASTRONOMICAL OBSERVATORY II
12/7/68
FIRST ORBITING TELESCOPE



DISCOVERER XIV
8/18/60
JETTISONED FIRST RECONNAISSANCE FILM



INTELSAT I (EARLY BIRD)
4/6/65
FIRST COMMERCIAL COMMUNICATIONS SATELLITE



EXPLORER I
1/31/58
FIRST U.S. SATELLITE.
DISCOVERED VAN ALLEN BELT



ECHO I
5/13/60
DIA — 100 FT.
PASSIVE COMMUNICATIONS REFLECTOR



SPUTNIK I—U.S.S.R.
10/4/57
FIRST SUCCESSFUL ORBIT

Soviet Premier Nikita Khrushchev had given warning. "We will bury you." But capitalism seemed to be working well in the months and weeks before *Sputnik* took off. Engineers just out of college could aspire to a starting salary of \$10,000 a year. It was enough to live well. A half-chicken dinner at Howard Johnson's in New York cost \$1.95. A Chevy 2-door V8 sport coupe went for \$2399. The sticker price on Ford's Custom 2-door V8 sedan was \$1772. The cover price of *POPULAR MECHANICS* was 35 cents.

American scientists had good reason to be confident. More than a year before *Sputnik*, U.S. rocket designers were closer than most people knew to overcoming the technical problems of launching a satellite. As it was explained to high school students in the mid-1950s, the problem was like trying to keep a marble circling inside a funnel.

If it moves too fast, the marble shoots out of the funnel. Too slow, and it drops down the funnel's hole. Step One in satellite science is accelerating the satellite to the precise speed where centrifugal force balances gravity. *Sputnik's* elliptical path through space required an injection-into-orbit speed of 18,000 mph, or 5 miles a second.

The algebra of such an achievement was second nature to the former German rocket designer Wernher von Braun. Recent interviews with his contemporaries indicate that in the early 1950s, he worked on detailed plans for launching an American satellite, although an informal security-classification system had prevented him from describing the plans publicly. But von Braun and many members of the team of the Army Ballistic Missile Agency (ABMA) knew that they could have lofted a satellite on September 20, 1956.

That was the date of a highly secret test flight of a 3-stage rocket that looked as though it had been put together by

committee, because it had. The first stage was a liquid-fueled Redstone built by ABMA, in Huntsville, Alabama. Two upper stages, one inside the other, were perched on top of the Redstone's nose as if a juggler had been able to balance an oil drum on the point of a huge gumdrop. These stages, the "oil drum," had been built by the Jet Propulsion Laboratory in Pasadena, California. The first upper stage was a ring of 11 small, solid-fuel rockets, scale models built for testing another Army missile called the Sergeant. Nested inside this cluster was the second upper stage, comprising three more mini-missiles. A small, 84-pound dummy nose cone was perched on top of the two rocket bundles. Adding to the impression that the rocket was a juggling act, the upper stages were kept spinning, at 750 revolutions per minute.

"The upper stages had no guidance capability of their own," says Walter J. Downhower, who now does strategic planning and analysis for JPL. "So we spun them up just as a rifle bullet is spun as it goes down the barrel of a rifle."

Strange as this craft looked, it rose



AT5-VI
5/30/74
BEAMED TV SIGNALS
TO SMALL
GROUND RECEIVERS

COSPAS—U.S.S.R.
6/30/82
FIRST SEARCH AND
RESCUE SATELLITE

SBS I
11/11/82
FIRST SHUTTLE—
DEPLOYED SATELLITE

SPOT—FRANCE
2/1/86
FIRST COMMERCIAL
RECONNAISSANCE
SATELLITE

NAVSTAR
LATEST DEVELOPMENT
IN PRECISION
NAVIGATION
(DEPLOYMENT
PENDING)

DSCS III
(PRECURSOR TO MILSTAR)
HARDENED SATELLITE FOR
MILITARY COMMUNICATIONS
(DEPLOYMENT PENDING)

perfectly off the pad at Cape Canaveral that day in September, more than a year before *Sputnik*. The Redstone burned through the lower atmosphere, then leveled off and broke away. The upper stages fired in precise succession, their spinning evening out the irregularities in the burn patterns of the solid rockets. The acceleration continued to a velocity just short of the speed needed to balance gravity and remain in orbit. The dummy nose cone coasted on, over a range of 3400 miles, reaching a record height of 682 miles.

"Had we replaced the 84-pound payload of the missile by a fourth stage, this same missile would have been able to orbit," von Braun reported later, and current JPL rocket experts agree. But President Eisenhower had ordered a strict separation between satellite and ballistic missile programs, partly to prevent leaks of military secrets when an American satellite went into orbit and drew the attention of the world.

Project Vanguard, the Naval Research Laboratory satellite effort, was still months away from its first launch attempt when the Soviets fired the first

shot and let this country know how little we knew about space. Amid widespread ignorance about rockets, satellites and their capabilities, rumors sprouted like tailfins. Sky watchers in Texas, New Mexico and other states said they had seen an egg-shaped object several hundred feet long. A Coast Guard cutter reported a fast-moving, bright object over the Gulf of Mexico. Scientists in several countries speculated that the Russians planned to bomb the moon.

At first, President Eisenhower and his close advisers made head-in-the-sand responses to the Soviet news and subsequent American jitters. The day after the launch, Ike played golf while relaxing at his Gettysburg, Pennsylvania, retreat. Defense Secretary Charles Wilson tried to be reassuring. "Nobody is going to drop anything down on you from a satellite."

But Americans worried.

And Democrats sniffed out a rare opportunity, once-confidential material shows. A couple of weeks after the

launch, Lyndon Johnson's political adviser George Reedy wrote the senator and future president: "The issue is one which, if properly handled, would blast the Republicans out of the water, unify the Democratic party, and elect you president."

Even fellow Republicans pushed Eisenhower, who was genuinely surprised at all the surprise, to take decisive action. For example, Republican Senator Jacob K. Javits wrote the president a week after *Sputnik's* launch that the U.S. should establish a crash program to develop a defense against Russian ICBMs. A month after the launch, Ike received similar, top-secret advice from a blue-ribbon commission. The group headed by H. Rowan Gaither Jr., chairman of the board of the Ford Foundation, painted an alarming picture of the Soviet threat. And the report, presag-

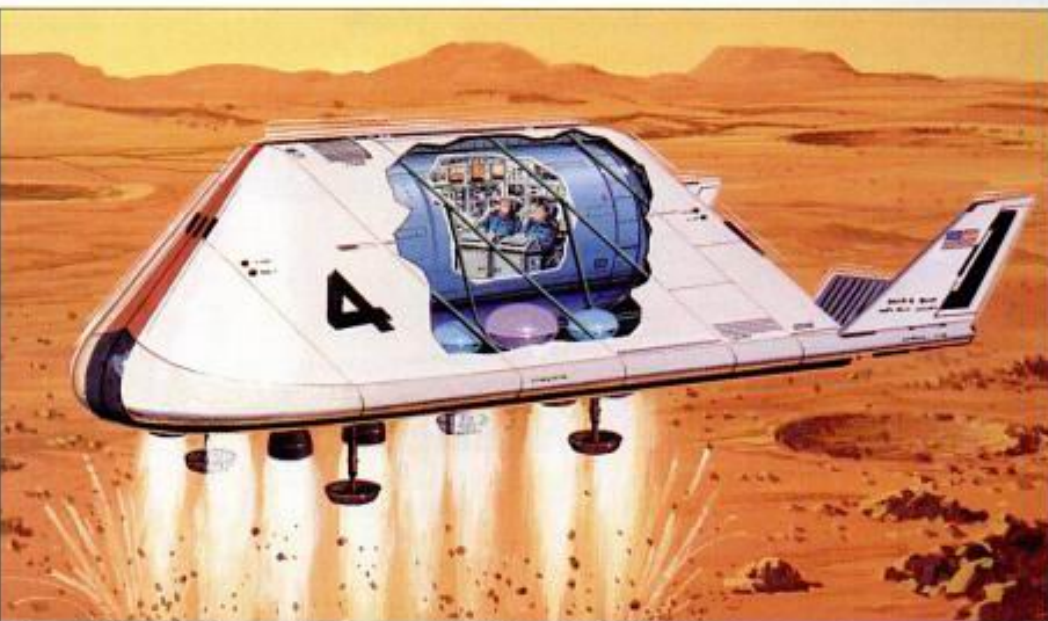
(Please turn to page 91)

Wings Of Mars

HUNTSVILLE, AL—A new Boeing concept for a Mars excursion vehicle draws more from today's flying-wing stealth aircraft, and less from the lunar landers that have shaped previous studies.

The high-lift-to-drag vehicle comprises a 65-ft.-long payload bay shielded by a curved, winglike thermal shroud. With body flaps and control surfaces on winglets, a pilot can steer during ascent and descent. The payload bay could contain 40,000 pounds of cargo or house a crew.

Boeing engineers conceived the craft to enable repeated takeoffs and landings during a mission, and to handle any heat buildup during



descent through the Martian atmosphere.

The concept was born of a now-completed study con-

tract with NASA's Marshall Space Flight Center. President Bush wants the mission flown by 2019.

Boeing's Mars vehicle fires eight rockets to cushion landing. Winglike shroud and control surfaces lend maneuverability.

Japan's Magnetic Ship

KOBE, JAPAN—The world's premier magnetohydrodynamic ship, YAMATO-1, (see "Jet Ships," page 60, Aug. '90) is complete.

Engineers from Mitsubishi Heavy Industries and Toshiba Corp. have finished testing the superconducting magnet assemblies that will help propel seawater through the ship's twin thruster ducts.

Launching the 97-ft., 185-ton craft is a complex affair. While the ship lies on a dry-dock cradle, technicians pump liquid helium into the magnets' cryostats. Once the magnets have chilled to 4° F

above absolute zero, they are energized to 4000 amperes of current from an outside gen-

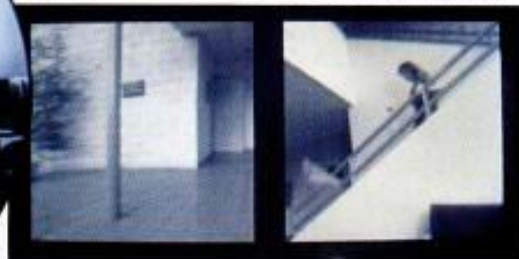
erator. A persistent-current switch locks in the magnet current. Then helium refrigerators on the ship whir to life, technicians cut the line from the external helium source, and the ship is ready to go.

Sea trials of the 8-knot vessel are scheduled to continue through 1992.



Looking Around

KNOXVILLE, TN—Can you scan a remote camera across 180° without moving parts? A NASA contractor has answered



Omniview camera uses image processor to correct distortions in fisheye image.

the question with a system that shunts digital pictures from a fisheye lens through an image processor.

In the Omnicam system, developed by TeleRobotics International, a single printed-circuit board flattens distortions out of the fisheye imagery. The remote operator uses a joystick to crop out the area that will undergo correction. The system can simulate panning, tilting and even zooming. And because a fisheye lens has infinite depth of field, everything is in focus.

Possible applications include target acquisition, telerobotic activity and surveillance.



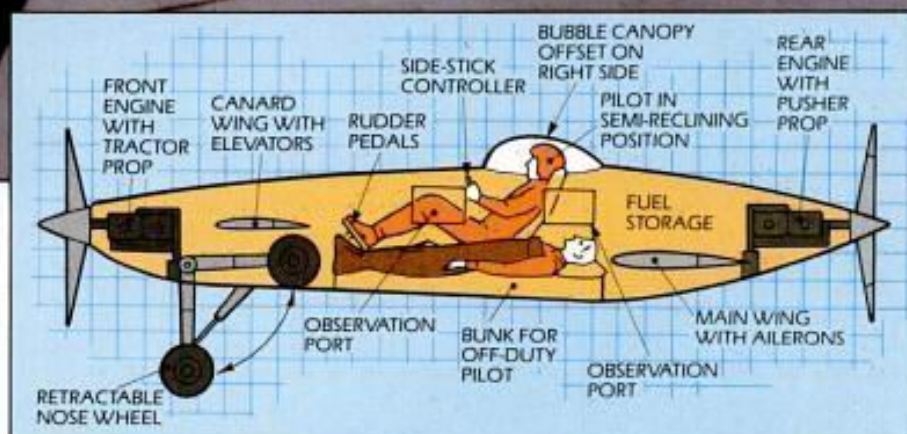
Voyager's awesome 111-foot wingspan is 3 feet longer than that of a 727 jetliner. Note tiny bubble canopy on right side of cigar-shaped fuselage.

Soon: First Nonstop Flight Around The World

BY SHELDON M. GALLAGER
Photo by Bruno R. Michetti

Sometime in the next few months, two daring young pilots will shoe-horn themselves into a cockpit not much bigger than a bathtub and set off to accomplish what no man before has ever attempted—the first nonstop, non-refueled flight around the world, a distance of some 25,000 miles. If successful, they will mark one of the great milestones in aviation achievement. No one else has even come close. The current record for nonstop, non-refueled flight was set in 1962 by an Air Force B-52 on a 12,532-mile hop from Okinawa to Spain.

The craft that will attempt this global feat, called the Voyager, is a weirdly awesome sight. Conceived by Burt Ru-



Cutaway of fuselage shows cramped quarters where pilots may live for up to two weeks.

tan, famous for his innovative home-built sports planes, it represents a striking departure from traditional aircraft design. Its long, slim main wing stretches an incredible 111 feet from tip to tip—3 feet longer than the wingspan on a Boeing 727. A shorter canard wing on the nose, a familiar Rutan trade-

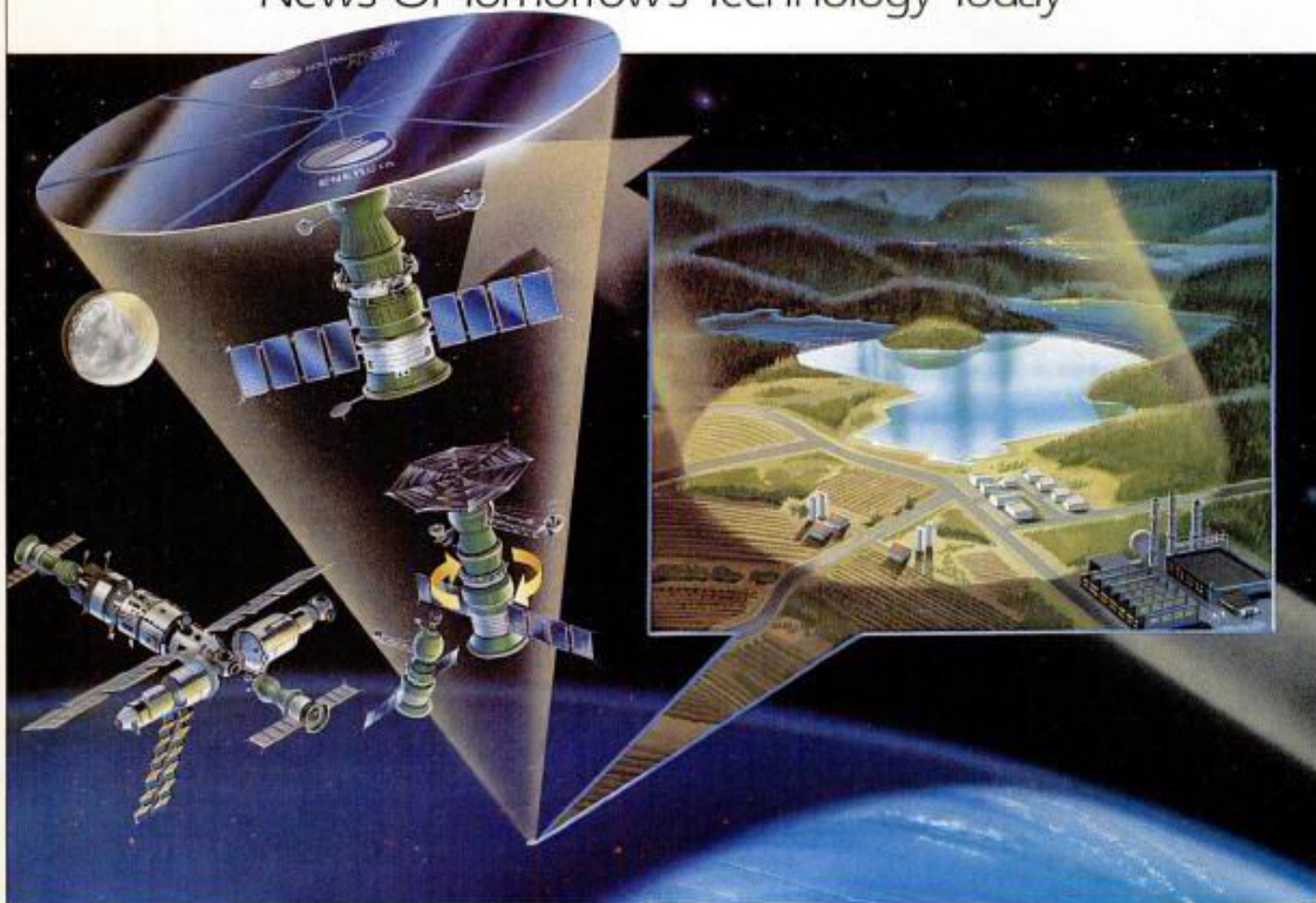
mark, adds lift and stability without the drag of a conventional aft-mounted horizontal stabilizer.

At the center, flanked by two 29-foot-long outrigger tail booms, is a small, cigar-shaped fuselage pod less than 40 inches wide with an engine at either

(Please turn to page 124)

TECH UPDATE

News Of Tomorrow's Technology Today



Gigantic Russian Space Mirror Turns Night Into Day

KALININGRAD, RUSSIA—The Russians seized the spotlight last February with the most imaginative space experiment in years. Cosmonauts aboard the space station *Mir* turned loose a huge orbiting reflector that lit up night landscapes by bouncing sunlight beyond the edge of darkness.

Dubbed *Znamya* (Russian for "banner"), the 65-ft.-wide sheet of aluminized plastic umbrellaed out from one of the *Progress* unmanned cargo craft used to resupply *Mir*. An electric motor pinwheeled the reflector to keep it flat.

As the *Progress* orbited, its maneuvering thrusters

cocked the spacecraft at the right angle for *Znamya* to catch a sunbeam and ricochet it Earthward. The reflected beam whipped across Earth's surface, creating a 2.5-mile-wide spot that traveled at orbital speed. Observers said the split-second illumination was like the light of a full moon tripled.

The space enterprise NPO Energia, which runs *Mir*, assembled a Russian consortium to pull off the project. Planners would like to loft a constellation of 100 orbiting reflectors that would prolong day-

light in high latitudes, aiding farmers, search-and-rescue teams and construction crews.

Znamya solar reflector bounced sunlight into darkened landscape during 5-hour experiment last February.

Highlights This Month

- **Get Up And Go**—More maglev proposals from American industry.
- **To See The Sea**—Laser scanners cut through the fathoms.
- **Diamonds From The Rough**—Modern alchemists turn graphite into gems.
- **Turbo Booster**—New *Pegasus* rocket gains giddy-up from jet engines.
- **World's Most Boring Machine**—Megamole digs tunnel for Super Collider.
- **Parking Lights**—Lasers to usher in night-flying naval pilots.

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POPULAR MECHANICS

AUG. 1968
50 CENTS

What
Owners
Think of
Torino
and Dart

Bombardier's New *SEA-DOO*

The Jet That
Almost
Flies

BUILD PM's
GAS-POWERED
MINI-TRUCK

Page 140



*Please, Mr. Automaker:
Can't You Cure These Headaches?*
(An Open Letter to Detroit)

The New All-Out War on Forest Fires

Chicago's Next Airport: In the Middle of Lake Michigan?

Weekend Projects to Modernize Your Home ☐ Now! *Water-Based*
Epoxy Paint ☐ Buying a Van? How Ford, Chevy, Dodge, VW Compare

they're fast, but most have propellers extending below the hull. Generally, the props are shielded, but they still can present problems. Some people claim they are unsafe, others feel they draw too much water.

But Sea-Doo doesn't have a prop—it uses a water jet. And only three inches of water is needed when the machine's at rest—less when up on plane.

Bombardier, this summer, is testing its new scooter in several areas of North America. The company expects to swing into normal production next season.

The power behind each Sea-Doo is a 320-cc, 2-cycle Rotax motor that develops 18.5 hp. Through a system of four belts, this motor has direct drive to a Berkeley jet pump. Once on plane, the jet will push Sea-Doo at about 25 mph—depending on load.

Bombardier says its new scooter will handle a load of 250 pounds. But in fact, you don't want to put much more than 200 pounds aboard.

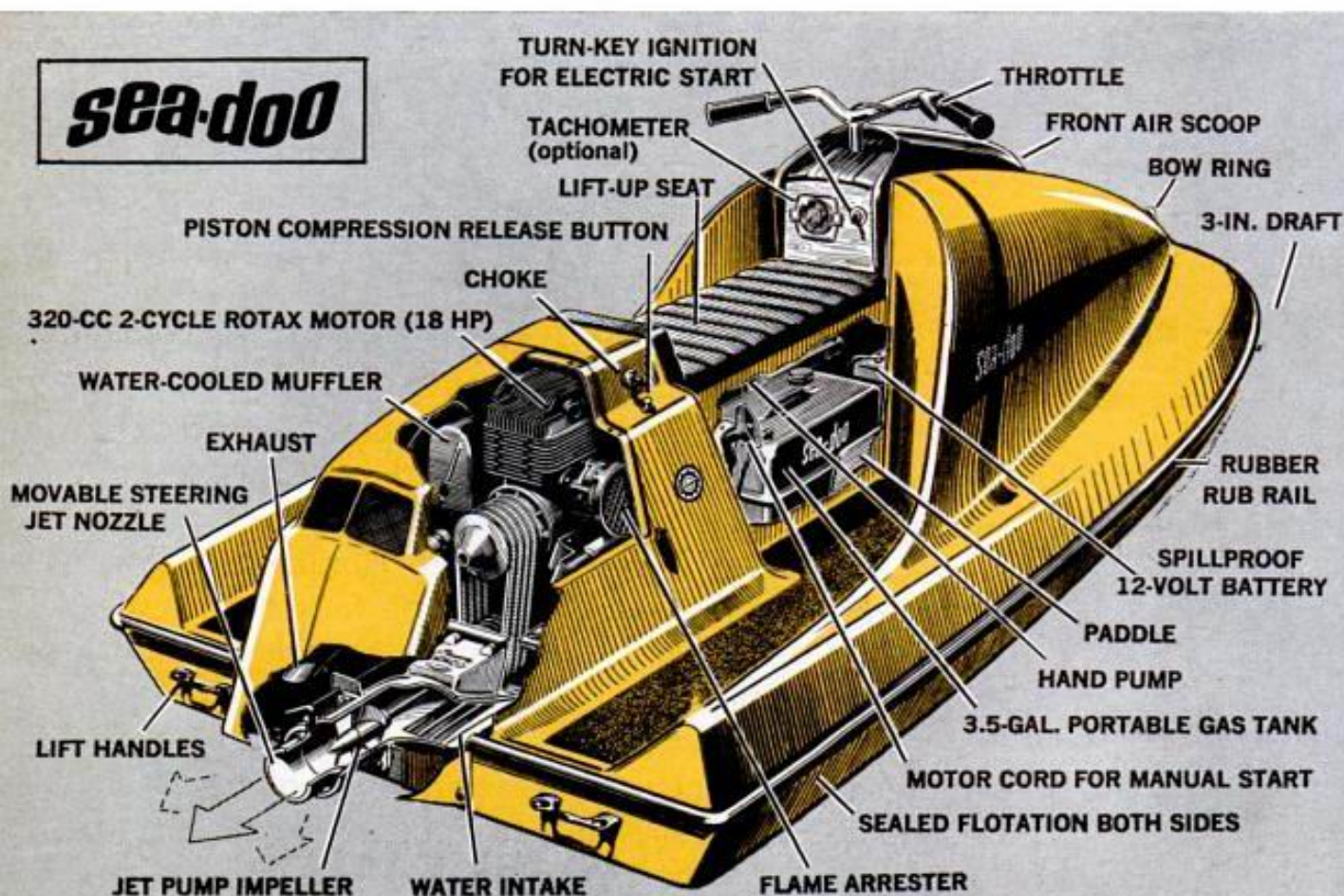
The lighter the weight, the quicker you'll get her up on plane. With my

weight pushing the 200-pound limit, I found I really had to lean forward to get Sea-Doo up on the step. Actually, I had to try to push the bow down with my left hand as I kept the motor wide open with my right grabbing the handlebar throttle.

But once on plane, I flew. I found myself riding Sea-Doo like a snowmobile. I stood up and jockeyed back and forth—hiking my weight out on every turn. I was surprised though at the stability of this machine. Sea-Doo is almost elliptical in shape. It's 7½ feet long and 5 feet wide. No matter what I did under way, I always felt I had complete control, and never did I feel that she would break away and spill me.

I even tried standing with both feet on one side while going 25 mph. Even in a turn Sea-Doo was stable.

Next came the spin-out test. Again doing 25 mph, I raced down a long straightaway. When I thought she was at top speed, I spun the handlebar. The jet swung her stern around. I hung on while doing a 360° spin. After the spin, I was almost dead in the water. The





JUMPING OFF a ramp built at the end of a dock can be loads of fun. Note that use of a water-jet pump eliminates any need for a propeller that hangs below the hull. Except for several stabilizing skegs, the bottom is smooth. Fiberglass hull easily takes pounding when you land

ZIPPING ALONG on relatively calm water makes for easy maneuvering, as you can see from look-ma-no-hands operation. Bombardier says the machine functions well in anything up to a two-foot chop. For saltwater operations, all motor surfaces are treated to resist corrosion

STABILITY is an asset in this machine. Though you might think it's about to tip over—it never did, even with the driver hiked way out to one side. He could have flipped it at this point if he wanted by giving an extra yank on the handlebar. But this would take a deliberate effort



HURRICANE!

When Nature Lays On the Lash

By JAMES M. BERRY

SHE BOILED IN FROM SEA the morning of Sept. 20, 1967, with the force of 20 atomic bombs a second. Within two days, Hurricane Beulah had devastated 40,000 square miles of Texas with 160-mph winds, 30 inches of rain and 97 tornadoes sparked by the maelstrom. Wind-driven floods crumpled steel and concrete levees, caused entire towns to be evacuated and made hundreds of square miles of citrus-growing land resemble ocean. Thousands of poisonous snakes, whose natural habitats were disturbed, terrified survivors. When she was through, Beulah had cost 11 lives and \$1 billion in property damage. Beulah was bad news, but so are the other six



HURRICANE SPOTTER PLANE

TOP OF HURRICANE ABOUT 40,000 FT

HURRICANE

EYE

WARMEST AIR NEAR CENTER

10 TO 30 MI
RAIN BAND

WINDS WHIP UPWARDS AT 300 M.P.H.

HURRICANE
75 TO 200
50 MI RADIUS

SEASWELLS

FORWARD
MOVEMENT OF
HURRICANE ABOUT
20 MI. PER HR.

WARM
WATER LADEN AIR
DRIFTS TOWARD CENTER
AT 10 TO 25 MI. PER HR.

SWIFT HIGH ALTITUDE WINDS

The Anatomy of a Hurricane

A typical hurricane bears down on the Florida coast at a relentless 20 mph. Warm, moisture-laden air from the Caribbean forms a gigantic counter-clockwise spiral. Heat from this rising vortex is carried away by high-altitude winds that create a chimney draft, evaporating wind-driven sea spray, increasing the hurricane's warm-air supply and boosting it to 40,000 feet. Devastating winds are racking Key West (left) and the sea surge is hammering Cape Kennedy and Daytona Beach (right). The eye will pass just north of Miami.

Illustration created especially for Popular Mechanics by Herb Malt, Sid Zigas and William Seifert.

10 TO 30 MI.
RAIN BAND

JACKSONVILLE

DAYTONA

WINDS
M.P.H.

GALE FORCE WINDS

400 MI. RADIUS

SEASWELLS, FIRST INDICATION
OF HURRICANE